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FEATURE ARTICLES

MATERIALS & METHODS MANUAL NO. 38

ENGINEERING FILE FACTS

SEMI-ANNUAL INDEX

DEPARTMENTS

NEXT MONTH: Elimination of Steel Basing Point System Would Have Varied Effect of Consuming Industry . . . High-Speed Heating of Metals by Gas and Induction Methods . . . Aluminum-to-Copper Welds . . . Electrically-Conductive Rubber . . . New Magnesium Alloys Offer Superior Properties . . . Wooden Dowels Solve Fixturing Problems in Brazing Steel Laminations . . . PERMANENT MOLD CASTINGS—Ferrous and Nonferrous (Materials & Methods Manual No. 39)

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The MATERIALS OUTLOOK...

ALUMINUM AND A LARGE AIRFORCE—Aluminum producers face the prospect of an extensive aircraft building program with something less than enthusiasm. After working for a long time to introduce aluminum into markets previously closed to that material, there is a strong likelihood that the supply situation in aluminum will be such that newer converts will be forced to switch to some other material. Past experience shows that an important percentage of such substitutions become permanent.

MONEL FOR ROOFING—Another entry is preparing to fight for a place in the metal roofing field. International Nickel Co. has announced development of a Monel sheet especially for this type of application. Earlier use of Monel for roofing result in estimates that this material will last in service for more than 100 years.

FOREIGN STEEL DEMANDS—Although it is still anybody's guess, a top steel executive estimates that combined steel requirements for all current essential programs—ERP, defense, freight cars, housing and oil refineries—will approximate 17,500,000 tons annually. Since current shipments to these users have been running to 14,000,000 tons annually, about 3,500,000 tons will have to be taken from other uses, less that steel resulting from capacity increases.

INSIST ON HIGHER COPPER—Canadian copper producers who have been predicting 25-cent copper (now 21½¢), as commented on in these columns in May, insist their prediction is correct. They point out that with lead at 17½¢, the margin between lead and copper is too narrow, and in this inflationary period any correction will be in the nature of a rise on the lower item, rather than a decline of the overly high item.

NICKEL PRICES—From Canada, where the bulk of nickel used in this country is produced, comes word that nickel prices will rise substantially before the end of this year. Nickel is one of the few metals which has not jumped in price for several years. In fact, U. S. prices dropped 1¼¢ some months ago to conform to an equal drop in duty. Gilbert C. Monture, Chief, Mineral Resources Div., Dept. of Mines & Resources, Canada, North America will not lock supplies of nickel for many decades. Not only are present working mines amply supplied, but new discoveries make the supply situation exceedingly optimistic.

MAGNESIUM EXTRUSION PRICE REDUCTION—The Dow Chemical Co. recently announced a new pricing system effective on all new orders received for magnesium extrusions. The change will result in an average price reduction approximating 10% and bring many extruded shapes into direct competition with aluminum. While the 10% figure is an average, reductions on the heavier sections of common alloys will be as great as 15%. Reductions will be less in light, complex shapes. Prompt deliveries are promised even with a greatly increased demand.

SELECTING PLASTICS MORE WISELY—Realizing that plastics as a group have often suffered in reputation from misapplication, the S.P.I. on behalf of the industry is launching an educational campaign. The campaign, which will include informative labeling on consumer products, is designed to help in the proper choice of a plastic material for any given application.

(Continued on page 4)

The Materials Outlook *(Continued)*

RADIOACTIVE MACHINE PARTS—Radioactive strips or rods of metal are being used in machines that develop static such as those for rubber working, and plastic coating equipment. In the case of coating machines, static which could ignite fumes from solvents employed, radioactive alloy strips placed in the static field will ionize the air, making it a conductor so that the static electricity will be drawn off through the strip. Polonium can also be plated on a metal strip as a static dissipator. There is no danger from the radioactivity of polonium since it does not emit beta or gamma rays. The alpha rays emitted serve as static dissipators.

GOVERNMENT SPECIFICATIONS RELAXED—Complaints of metal producing industries against unrealistic government specifications of metals sought for stockpiling are finally having some effect. The Munitions Board, as a group, has apparently reached the realization that only a small part of the supply of any basic material is of the highest grade. Likewise, it is now accepted that to meet Munitions Board requirements would strip industry of its needs. Now a balance is being proposed that may relieve some of the tightness which has plagued superior grades of zinc, copper and a few other materials.

ALUMINUM SOIL PIPE—Niagara Falls, N. Y., is expected to approve the use of aluminum alloy soil pipe in residential construction in that city. Cast iron soil pipe is extremely hard to get and the shortage is expected to get worse. Aluminum pipe is priced about the same as for cast iron pipe, but savings are looked for because of easier handling and lower freight charges.

CONDUCTIVE GLASS—Rumors have been current for some time concerning electrically-conductive glass. Now it appears definite that such glass will soon be available to industry. One glass of the type, just emerging from the laboratory, is said to be capable of attaining temperatures between 600 and 700 F. An expected use for conductive glass is in the chemical industries for apparatus used on processes where chemical reactions must be watched. Another obvious use is in automobile and bus windshields to prevent frosting during bad weather.

ALUMINUM IN AUTOMOBILES—During the past few years aluminum has been used in increasing quantities in motor cars. It appears that the major use of the light metal in automobile bodies will not be attained until certain manufacturing techniques can be developed. For instance, with steel bodies sections and panels are spot welded together and the depressions filled with solder so that no joint is visible. Solder will not adhere to the aluminum and furnish a good base for the paint. Automotive designers generally are anxious to use aluminum as liberally as possible because of the advantages attained through weight savings.

LEAD STILL TIGHT—Although under today's conditions the supply of lead could run about even with demand, strikes and labor shortages have kept this from happening. Leaders in the industry do not yet see the time when consumption and production will come into balance. Now that the storage battery demand has fallen off somewhat, the cable industry and others are stepping up their use of lead.

AMPLE VANADIUM—Usually we depend upon foreign sources for from 1/4 to 1/2 of our vanadium supply. The intensified production of uranium, of which vanadium is a by-product, in Colorado, Utah and Arizona means that our domestic production of vanadium should be sufficient for our needs and perhaps leave a surplus for export.

AN EDITORIAL

A Spade Is a Spade

This is not Gertrude Stein-ish mumbo jumbo, designed to leave you more benumbed and confused than the world and its affairs have done already. Rather it is our plea that American materials engineering activity, now emerging as a powerful and increasingly cohesive industrial function, be freed of all possible restraints on its future development—particularly those style-cramping limitations imposed by calling things by the wrong names.

During a recent swing around the circuit we made several calls, some under a thin cloak of anonymity, to determine the nature and number of different job titles borne by men who are actually functioning as materials engineers—in other words who spend all or most of their time on problems associated with the materials used for somebody's products.

We found many men up to their professional necks in materials engineering (as distinct from mechanical or electrical design, or production supervision) but only a small proportion of them bore the title "materials engineer." The following designations are the ones most frequently carried by those materials engineers who are forced to masquerade as something else: metallurgist, metallurgical engineer, standards engineer, specifications engineer, application engineer, process engineer, and just plain engineer. In a majority of cases these men would evidently prefer a materials engineering title to the one they now carry, and in all cases their individual tasks, and especially their broad industrial mission as a group, could be more effectively accomplished if they were called what they actually are—materials engineers.

The "metallurgists" in this group constitute an interesting (and the most numerous) misnamed example. There are of course several kinds of "metallurgists," all very important in our industrial structure—those who process ores, and refine and smelt metals as raw materials; those who formulate alloys and control metal melting operations; those who conduct research on the constitution and structure of metals; and those whose expert knowledge of the different characteristics of metals and alloys is applied in selecting and processing them for industrial products. This last group, the *materials engineering* metallurgists, should obviously be titled "materials engineers," for they are performing exactly the same functions as the increasingly large body of men who are actually called materials engineers, even to the extent of appraising and applying nonmetallic materials along with metals and alloys.

Conversely we encountered instances where the change to a materials engineering title had been achieved, to everyone's satisfaction, either through the establishment of a "materials" or a "materials engineering" department and a general retitling, or through the simple recognition of an accomplished fact in individual cases.

The important point is that this is the trend; it will become the general situation in time as materials engineering continues to grow as a specific professional activity in industry. But there are still thousands of plants who do not receive the public credit they deserve for the advanced materials engineering work of their metallurgists or standards engineers or application engineers, simply because they've disguised the activity behind inaccurate titles.

Why not call a spade a spade?

FRED P. PETERS

Materials & Methods
JUNE 1948

Performance tests conducted on complete jet engine assemblies reveal much valuable data on materials and design. (Courtesy: Westinghouse Electric Co.)

The Principles and Uses of Simulated Service Testing

by L. L. WYMAN, General Electric Co.

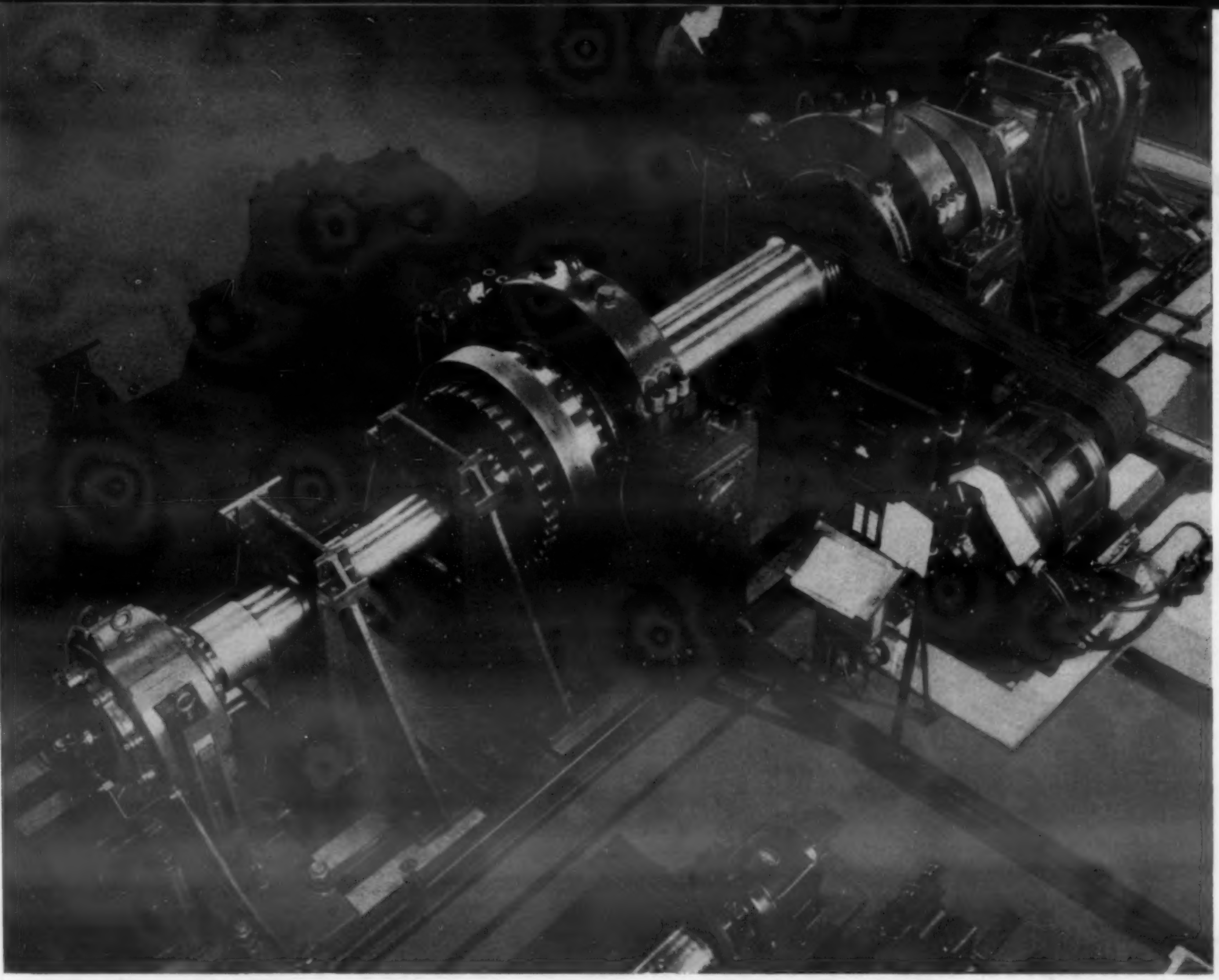
DESPITE THE EXISTENCE OF many kinds of testing methods, which "accept" thousands of tons of materials daily, there are still too many unpredicted service failures of materials and designs. It is also evident, when one considers established design practice and specification of materials, that the high safety factors usually incorporated in designs are all too frequently nothing more than "ignorance" factors. Granting this, it seems apparent that the test methods being used in many cases are deficient in their ability to detect faulty material or to predict with sufficient accuracy the suitability of materials or designs for actual service.

Mr. Wyman is chairman of the ASTM's Administrative Committee on Simulated Service Testing.

Information and data resulting from simulated service tests can frequently prevent premature service failures and promote more efficient design and use of materials.

To attack these problems of premature service failures and to foster more efficient design and use of materials, we must put greater effort into the determination of *all* service factors and uncontrolled service variables. An important phase of this effort coming into recognition is simulated service testing.

Simulated service testing may cover the range from specific tests on completed parts to tests on subassemblies and service-life tests of the completed equipment. It is not the role of present efforts in simulated service testing to establish rigorous test methods for each and every kind of part or product, but rather to (1) foster more adequate analyses of service conditions, (2) promote the development of suitable short-time test methods, (3) inspire a thorough scrutiny of present test methods with re-



Full size locomotive driver axles are subjected to simulated service tests in this huge axle testing machine. Speeds comparable to 150 miles per hour can be achieved. (Courtesy: The Timken Roller Bearing Co.)

spect to their ability to predict serviceability, and (4) promote a closer integration of materials, design, environment, and service life.

The basic purpose of all materials testing is to determine whether or not the materials are satisfactory for the job—that is, the determination of material quality in terms of serviceability. In order to satisfy all conditions it is essential, in testing, to give proper recognition to three basic factors: (1) materials, (2) design, and (3) environment while in service. Furthermore, it is not only the recognition of these factors, but the evaluation of each and weighing the importance of each relative to the others which comprises the controlling factor in serviceability.

Of the three basic considerations, environment is the least recognized and understood. This factor covers conditions of service such as temperature effects, humidity, corrosion, overloading, shock, vibration, and a host of other conditions, each having various degrees of importance, amenability to control and susceptibility to duplication for test purposes.

During the past war, unusual service conditions such as low temperatures, high altitudes, intermittent sea-water and salt air exposure, high temperatures, humidity, and fungus caused a tremendous amount of equipment failure, thus serving to emphasize the role of various factors of environment in determining serviceability.

Most of the above-mentioned environmental factors are quite obvious, but they should serve as a warning that service failures are not always as simple as they may appear at first glance. Too frequently one observes parts or units which have been made from seemingly proper materials, with nominally proper design and engineering, but which have failed in service—or maybe failed on just certain service applications. Obviously there must be one or more unrecognized factors which were in control in such instances; and until they are recognized, evaluated, and subjected to adequate test procedure—all leading to proper control methods—the possibility of premature service failure still exists.

Many of the tests presently used are unable to predict or assure satisfactory service. These tests should therefore be re-evaluated in terms of what they can foretell and should be modified; or new tests should be devised which will pass only materials of assured service life. To accomplish this it is necessary to analyze the service conditions from the standpoint of the three major control factors. It may then be pos-

sible to establish a simulated service test on some of the parts and assemblies, and subsequently progress to the individual pieces. Each step must involve a thorough analysis of materials, design, and environment and their relative importance. Finally, there should result a set of test conditions from which one can determine whether one of the standard test methods is applicable, or whether a new test procedure must be devised for the particular purpose which will simulate actual service conditions.

A Typical Case

To illustrate the analysis that should be followed in arriving at the proper test or tests, let us take for an example the writing board of the steel desk at which this article is being written. It consists of an inverted shallow box; the lower edges of the sides are turned in 90 deg.; those on the ends are turned in 180 deg. The steel, let us assume, is a quarter-hard, low-carbon sheet that carries a specification of some 20% elongation in 2 in. in tensile testing, and is reputed to be able to take a 90-deg. bend along the grain and a 180-deg. bend across the grain.

Assuming a stock thickness of 0.040 in. and a moderate bend radius, it is found that according to the standard tensile test, we have "run out" of elongation on the 2-in. gage length long before the bend is completed, and the edges should have broken during fabrication. But they did not break. The elongation around the bend may be near 40% but the bends are clean and smooth without an indication of the orange-peel structure characteristic of an over-drawn part. It is true that the combination of elongation and reduction area in the ordinary tensile test may hold some promise of sufficient ductility, but this is not a positive determinant.

What, then, is the difference? The difference consists of a number of factors, each of which has some bearing on the operation. Of these, it should be obvious that this problem concerns a wide sheet which is to be given several sharp bends; thus, the focal points should not be the elongation over a 2-in. gage length of a narrow specimen, particularly one of such geometry that the lateral contraction affects the elongation. Nor is it the result of a bend test on a sample strip where a similar relationship is effective. This problem does, however, concern the limiting useful elongation in a very short gage length along the outer fibres of a bend in a specimen which is so wide that there is little if any lateral contraction to affect the almost pure tension on the outer fibres.

Exhaustive tests on bends of this kind, supplemented by careful analysis of what is actually taking place, have led to the use of special tensile test samples where elongations can be determined over very minute gage lengths through the use of photographic grids in the sample. Also, the basic considerations are true-stress and true-strain rather than the apparent stress-strain data resulting from most present day tensile testing. When suitably wide (and short) samples are used, the elongation test results on these minute gage lengths may be used to calculate the minimum bend radii for simple sheet bending of this kind. Thus, by careful analysis of the problem it becomes possible by means of a test method which simulates the fabricating method to not only determine precisely how much deformation the metal will take under the given conditions, but to carry on further to where one can in some instances predict the performance and determine the bend radii for the instruction of the die-maker. Furthermore, comparisons have shown that the calculated values are more nearly correct then the bend radii determined the "hard way" in the plant.

This enlightened viewpoint as to what is actually taking place during a fabricating operation such as just described is new to most of the metalforming fraternity. Historically, this process of metal forming has been an art, but, because of the newer methods of testing, it is now well on the road to becoming a science.

Technical men who are vitally interested in the development and use of methods of test may indeed be thankful to the gigantic growth of the aircraft industry during the war because of the impetus it gave to the study of metal plasticity. The urgent demand for more and more plane parts necessitated a tremendous expansion in sheet metal fabrication and the wide dissemination of forming "know-how" into plants but little accustomed to this work. Also, the newer designs of combat planes involved the production of more complicated shapes as well as the use of new, higher strength materials. Altogether, the problems in metalforming were astounding. However, with the assistance of government-sponsored research, most of these problems were solved, and usually through the application of the fundamental concepts of metal deformation, flow, etc.

Stresses set up during forming operations can be accurately determined by simulated service tests on pieces of gridded metal forms as shown here.

New concepts? No, indeed, for some of the fundamental theories and mathematical expressions for plasticity have been lying about almost neglected for the better part of a century. Disturbed but infrequently during the years by a small school of theorists, we now find some of these considerations—and many more new ones of present vintage—in the forefront of all intelligent discussions of metal deformations.

The original data for such work are usually developed by an empirical simulated service test wherein photographically gridded sheets are fabricated to the required shapes and the resultant strains are analyzed. Progressing beyond this, new test methods, which simulate the fabricating stresses and strains in terms of uni-, bi-, and tri-axial stresses have been developed and many of them reduced to mathematical formulation. Too, the applications have broadened from the original aluminum and magnesium alloys to the drawing of steels and to the stainless alloys.

Necessity has mothered this particular field of effort until it is presently one of the most active of the various fields of metallurgical research—the so-called "mechanical metallurgy." Its results will go far toward bridging the too great lack of understanding between the metallurgist and the engineer, and, in all probability, will eventually lead to the establishment of a number of new test methods by means of which metals can be intelligently evaluated for specific kinds of applications.

One of the prominent aircraft engineers working in this field once commented to the effect that a piece of metal doesn't know what's pushing it around, but it sure knows how much pushing it will stand! When the amount and kind of pushing our metals can stand can be defined by the metallurgist, then the engineer will be given data that are far more reliable than much we have today. Furthermore, these data will go far to aid the engineer in his design work because they will tell him the performance under many combinations of stress. Thus, if the design must be fixed because of functional reasons, the design stresses as measured by modern strain gages may rule out the use of certain materials. On the other hand, if certain materials must be used because of factors other than strength, then the deformation limits will guide the engineer to a safe design.

Simulated Service Testing Applied to Fatigue

In quite another field, that of fatigue testing, the principles of simulated service testing must be more widely applied. Fatigue testing is outstanding in the abuse and misuse to which it has been subjected. There are fatigue machines that spin the sample while it is acting as a cantilever for its load, others may wiggle the sample, some push and pull, while some just plain shake the specimen. Do they give reliable results which can be extrapolated to the actual part in service? By and large the answer is highly dubious, as may be witnessed by the numerous failures through fatigue.

The basic fault is usually not with the fatigue machines, but with the extrapolation from the test data on a sample, which in no manner simulates actual service, over to another size, shape, etc., which is to become an equipment unit. Because design has a very profound effect on fatigue, every precaution should be used to guard against this over-extrapolation of test results.

For example, the fatigue testing of high-temperature alloys for gas-turbine buckets presents a rather neat problem which has been closely simulated. The turbine buckets operate under rather high and diverse stresses; rooted at one end, they hang out in a hot breeze that is moving at no small velocity. The blades bend and flutter as they gyrate at tremendous speeds.

Any correlation of fatigue results from a cantilever tester, or results of bending a rod, or bar, or even a bucket itself on one of the available mechanical or magnetic testers with their heavy attachments to the sample would be fortuitous, to say the least. Thus, there arose the necessity of devising a new type of fatigue test which would accurately simulate the service condition of these blades. This was done by attaching a small, extremely light-weight piston to the end of the blade and obtaining the desired vibration by means of a "tuned" jet of air.

In this particular instance, the peculiar shape of a turbine bucket is such that the design is frozen; its extremely thin sharp edges are obviously a dominant factor in initiating fatigue fracture. In contrast to this, there are scores of instances which are less obvious, where the design factor is more subtle, and unless the parts are redesigned or the essential design factors are incorporated into the test procedure, the test results will be in error and service failure will occur.

While there is much to be desired in the present status of fatigue testing, efforts in this field have been of considerable value as a means of studying and developing materials. For example, specimens of the same material, but fabricated in different ways, may show quite diverse fatigue results. Further study may show, however, that if some metallurgical characteristics such as grain size are equivalent, then comparable test results will be obtained. Thus, the fatigue test may, in this instance, serve to aid in material development and improvement even though these same test data are not necessarily applicable to all fatigue applications for this material.

Corrosion Testing

Corrosion testing presents numerous unique problems because of the many uncontrollable variables involved. Most obvious, of course, are those dealing with exterior exposure in various locations. Corrosion experts can do very little to control either the weather or the atmosphere, thus they must resort to actual out-door exposure tests in various localities in order to determine serviceability. In accomplishing this a number of exposure sites typical of salt-air, industrial, semi-industrial, and suburban conditions have been selected; exposure racks have been erected; and numerous samples of materials, platings, paints, etc., have been placed for actual life tests. In addition, other tests have been set up for actual salt water and intermittent salt water exposure.

Unfortunately, these are long-time tests, and efforts to reduce these service conditions to short-time laboratory tests have met with only moderate success. The usual difficulty is the inability to obtain correlating results or to derive comparable test data from repeated tests or between cooperating laboratories. For example, corrosion tests in most carefully compounded artificial sea-water have shown highly erratic results, and indicate the need for the detection of still obscure factors which appear to exert control over the tests.

Such occurrences are not peculiar to corrosion testing alone—they happen in the best of testing circles—but corrosion testing seems to be particularly afflicted with such unfortunate instances. On the brighter side, some forms of weathering tests such as exposure to sunlight and a few stress-cracking tests have been reduced to accelerated laboratory methods with quite satisfactory results. On the other hand, laboratory tests such as the "salt spray" method are more or less empirical and do not simulate actual service. However, they do serve well to differentiate between materials.

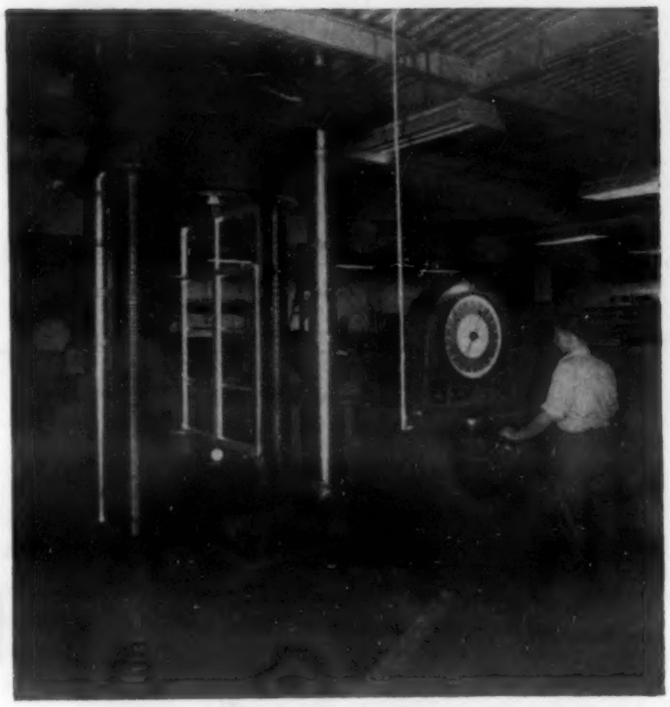
Because of the recognition of the inconsistency of many of their test results, there is a rapidly increasing effort among corrosion experts and corrosion engineers to cooperate in an attempt to progress much further in the direction of simulated service tests that are consistent and reliable—a very hopeful sign in this phase of testing.

Testing Structures

In the structural field, there has been a surprisingly small amount of testing performed on parts and sub-assemblies in simulated service. Indeed, while there are rigid specifications on many of the materials and shapes which are used, there are glaring deficiencies in the testing of the assemblies of these parts. Whether it be in a machine, an airframe, or the wall of a prefabricated house, the whole structure is a combination of design plus material. They are interdependent; thus, the sooner the technicians are able mutually to evaluate these two factors, the more rapid the progress will be through the range of simulated service to that of specific tests.

Currently, there is accelerated effort on the part of those interested in structural materials to enter the simulated service field; to devise simulated service tests for the evaluation of sub-assemblies, with a view toward both better design and consequently better material utilization without sacrifice of structural safety. These efforts are currently concerned with building panels, connections, trusses, arches, etc.

A war-time example of the interdependence of materials and design in structures is that of the cracked cargo ships. In this instance, "faulty material" was the customary complaint, coupled with a high degree of scepticism concerning the use of welding in ship fabrication. After several years of intensive materials research, and lately some actual structural tests, it would seem that while some considerable improvement might possibly have been obtained by improvement in material, the effect of design—as shown by the structural tests—was many times as



Shown here is a steel window sash being tested under loads similar to those imposed upon it in actual service. (Courtesy: The Steelcraft Manufacturing Co.)

great as that possible by potential material improvement.

The reader might be inclined to view the foregoing discussion as an indictment of present testing methods. To the contrary, it is an attempt to encourage a fair re-appraisal of these tests in the light of present day knowledge concerning the behavior of metals under various combinations of stress conditions. Furthermore, by indicating that newer testing procedures have been or may be developed which will give the necessary results, their earlier and more widespread use may be greatly accelerated.

This self analysis is of such importance that the American Society for Testing Materials has established the Administrative Committee on Simulated Service Testing. This committee has for its functions the supervision of the development and standardization of methods of test of simple or composite materials in actual or simulated service conditions and environment, insofar as performance has a bearing on the properties of the material.

Whether it be by means of simulated service testing in order to encompass intangible factors, or by the newer test methods dictated by better stress analysis and better understanding of multi-axial stress effects on materials, or by a re-evaluation of present test methods to determine their limits of usefulness, the primary objective of this committee is the establishment of methods of test which will reliably and consistently produce sound data at the earliest possible stage in processing and fabrication.

Much of this work must and can be accomplished through missionary work, and if the present discussion does nothing more than to shock a few chance readers from smug complacency into rank scepticism concerning some of our present testing methods, then the effort is amply repaid, and a portion of the objective accomplished.

By adding 0.35% carbon after fabrication, fabricating advantages of low carbon steel are possible on a part which must be through-hardened for the intended service.

Through-Carburizing of Low Carbon Steel Permits Purchasing and Fabricating Economies

by KENNETH ROSE, Engineering Editor, Materials & Methods

WHEN PROCESSING OR OTHER REQUIREMENTS dictate use of low carbon steel, but service conditions require a hardness in the piece unobtainable with low carbon content, such processes as carburizing or nitriding are frequently called upon. These processes permit taking advantage of the ease of forming, excellent weldability, and low cost of one material, and by a subsequent treatment in a furnace convert the surface to a hardenable steel, with all the advantages of a material of that type. These surface hardening methods have a valuable and well-defined place in the techniques of processing steel.

There are cases, however, where the properties associated with higher carbon content must be obtainable through the entire thickness of the workpiece. Surface hardness is satisfactory when the piece in service must resist wear or abrasion, but in such parts as springs the spring temper must extend throughout the piece. In other instances the strength requirements cannot be met by increasing the hardenability of the surface only. In the past, it has usually been necessary to adapt the processing requirements to a higher-carbon steel. Severe forming has been made possible by using frequent anneals, and machining has preceded hardening, with pressure quenches or similar operations to reduce distortion. Another solution has been the fabrication of the piece as a weldment.

A new approach to the problem has developed around the idea of using a low-carbon or low-alloy steel for the part, and, after fabricating, of carrying the carburizing process to the point at which the higher carbon content is carried *through* the entire thickness of the steel. In effect, the part is made of a low-carbon steel, and the finished piece is then transformed into higher-carbon steel in a furnace. It is an extension of the method of case-carburizing to produce a steel of uniformly higher carbon content, and is sometimes called *homogeneous carburizing*.

The process of transforming a low-carbon steel into a medium- or high-carbon steel in a furnace after the steel has been fabricated to final form is not, needless to say, simply a matter of heating in a carburizing atmosphere for a period longer than usual, though one method of through-carburizing is almost that when reduced to its essential terms. During case-carburizing the gaseous, liquid, or solid carbon from the carbon-rich atmosphere surrounding the work first diffuses into the surface of the steel, forming a high-carbon skin. This carburized zone gradually deepens, but the rate of penetration falls off logarithmically as the depth increases. The carbon content grades off steeply with depth, and the result, even when some of the carbon has penetrated to the center of the cross-section, is not homogeneous. Development of a higher carbon content in the steel homogeneous throughout the thickness of the piece is a long-time process, as might be judged from the graph (Fig. 1).

Through-carburizing with gaseous atmospheres can be accomplished by either of two methods, which might be stated briefly as follows:

(1) *Uniform atmosphere, long-time exposure.* The carbon obtained from the carburizing atmosphere is allowed to diffuse into the steel, first forming carbon-rich zones at the surface of the piece, then gradually

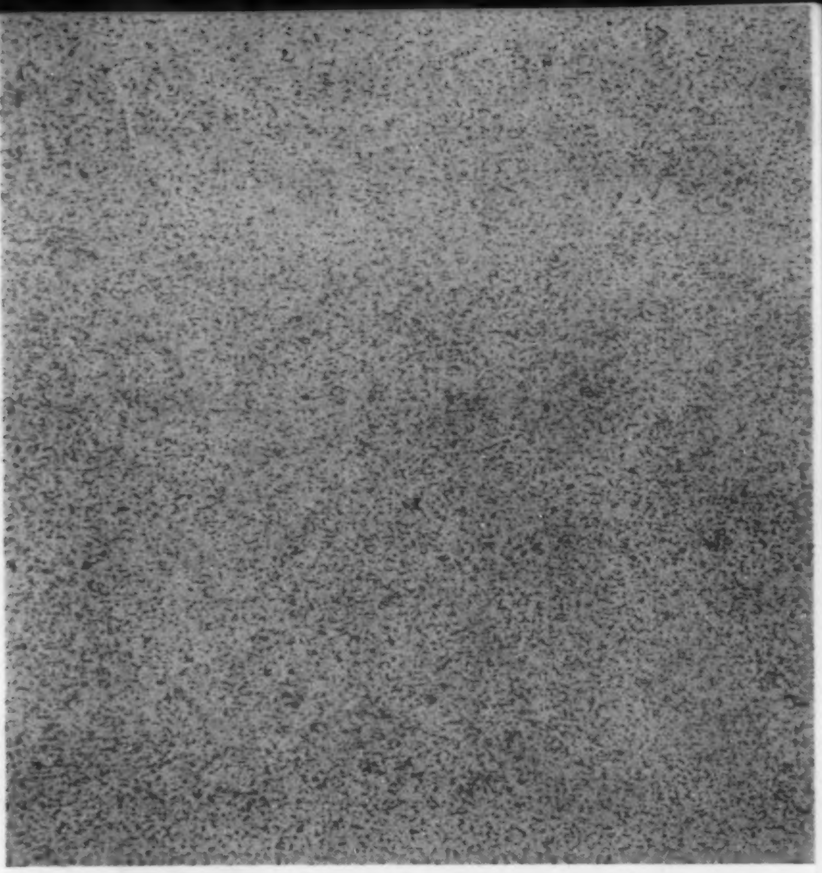
building up the carbon content throughout the cross-section of the steel. The carbon potential in the furnace atmosphere is held at the point that will be in equilibrium with the carbon in the steel at the desired carbon content.

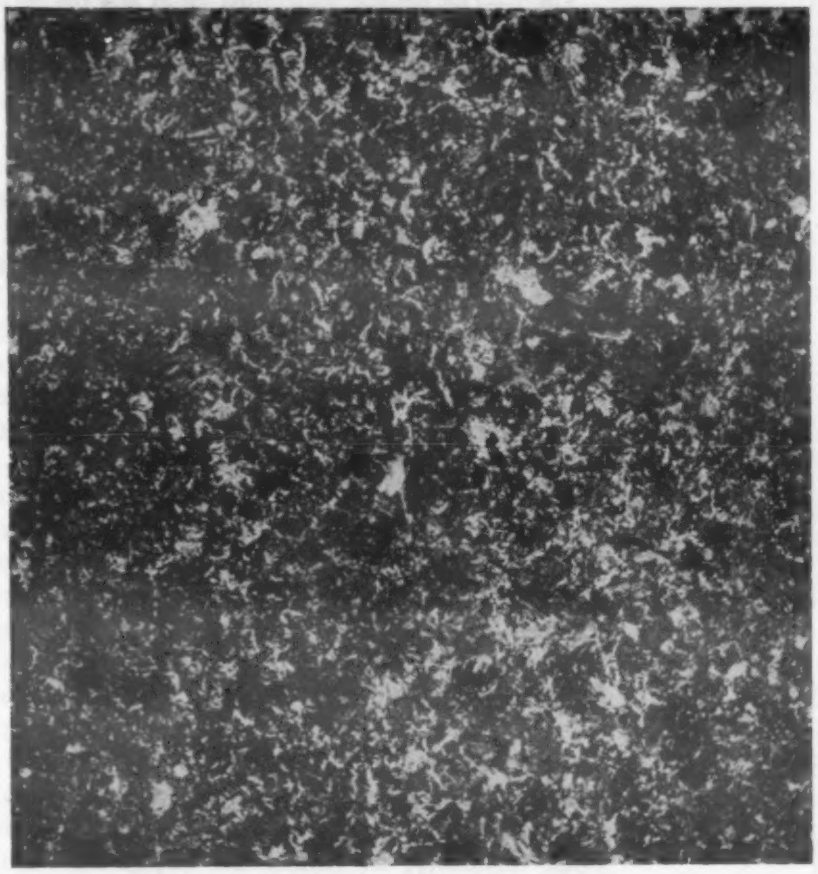
Features of this process are: (a) Controls are simple, as the carbon potential must not be adjusted after the carburizing has started; (b) the process works well even with a piece having different areas of cross-section; (c) with thin stock, the processing time is not excessive.

(2) *Atmosphere varied during process to obtain quickest carbon buildup.* Here an atmosphere with a high carbon potential is used at the start of the process to drive the required amount of carbon into the steel, and the potential is then decreased during a succeeding diffusion cycle. The initial carbon content is largely concentrated near the surface of the piece, and in the later stages this carbon already in the steel is distributed uniformly throughout the thickness of the piece.

Careful control of the carbon content of the gas is a prime requisite of this method of carburizing. If the workpiece has thin and thick sections, there is danger of building up a higher carbon content in the thin sections than is desired. Processing time is appreciably shortened, however, making this a relatively low-cost procedure.

Because of the time element involved in each process, a practical limit of about ⅛ in. or slightly more may be set upon the thickness of the steel that can be effectively through-carburized. This is a working limit only, as there is no theoretical limit to the ability to diffuse carbon into steel, and to develop a homogeneous structure afterwards.





These before and after microphotographs show the carbon addition made through the new through carburizing process. Top shows before treatment and below shows after treatment during which 0.35% carbon was added to the steel. (Magnification, 67X; Nital etch.)

Use of the process at Buick Motors Div. of General Motors Corp. will illustrate its mechanism, and will serve also to point up its role in metals engineering. The process in use there is of the second type, in which the concentration of available carbon in the gas is varied during the cycle and the total time for carburizing is reduced.

A clutch spring, in form resembling a truncated cone, was made from a steel disk about 8 in. outside

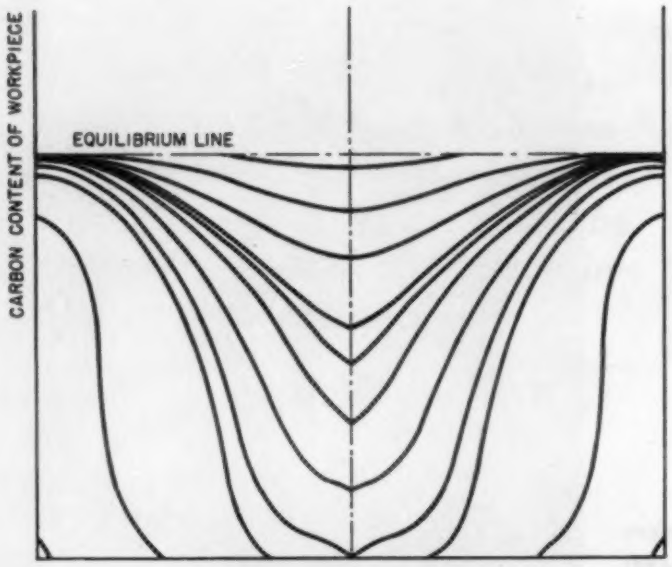


Fig. 1—This graphic illustration shows how the carbon content of steel builds up. For case carburizing, the carbon content of the steel almost never equals equilibrium with the carbon potential of the atmosphere.

diameter, with a 4-in. hole in the center. The finished disks were required to be 0.057 in. in thickness. These were made of SAE 1065 steel, originally tempered to spring hardness after forming. To obtain a good surface, free from any trace of decarburization, the plate was formerly bought oversize and ground to thickness. A spheroidizing treatment was used to give the metal a desirable structure. Cross-rolling helped to reduce directional properties in the stock. In spite of all these precautions, the springs were rather difficult to form and heat treat so that complete uniformity was achieved in the finished product.

It was decided to use a low-carbon steel for fabricating the spring, and to build up the carbon content of the formed piece to a point that would permit developing a spring temper. The steel selected was a low-alloy steel containing 0.15% carbon. Savings were immediately effected by buying the stock to finished thickness, and by omitting the cross-rolling requirement. Blanks of this stock were formed without difficulty, as might be expected with the low carbon content. The furnace treatment of the springs was then worked out so that the carbon content in the stock could be built up to 0.45 to 0.50%, through and through.

The carburizing treatment is accomplished in a pit type Leeds & Northrup furnace, electrically heated, with an alloy steel muffle or retort to contain the work and gases. Recirculating fans help to obtain uniformity in heating. The heating coils used 125 kw. at peak input. The heating cycle for the carburizing operation is shown in Fig. 2.

To obtain an efficient loading of the furnace and insure proper contact of all surfaces of the work with the carburizing gas, the formed pieces are loaded into a fixture in which 38 springs are held on each of nine rods, with 1-in. spacers between individual springs on each rod. A batch of 342 springs is treated in about 7 hr.

An important feature of the through-carburizing process is the selection of the furnace atmosphere. In the Buick operation, as set up by Floyd Harris, furnace engineer for Buick Motors, a carrier gas is used in combination with the carburizing gas, which is natural gas. The carrier gas is about 20% carbon monoxide, balance nitrogen. Carbon dioxide is held to less than 0.1%. The natural gas is rich in methane as the carbon-supplying constituent, and contains about 0.03 lb. of available carbon per cu. ft.

The carbon requirement of the work is as follows:

> Carbon content of the steel to be increased from 0.15% to 0.50%—0.35% to be supplied from the atmosphere 342 springs per batch X 1 lb., weight of each spring, = 342 lb. of steel, the furnace load 342 lb. X 0.0035 (= 0.35%) = 1.197 lb. of carbon to be supplied per batch

In order to insure a large excess of carburizing gas over requirements, and so to carry the rate of carbon absorption as high as is practicable, natural gas is added at the rate of 70 cu. ft. per hr. during the initial carburizing phase. This includes about the first 2¼ hr. of the process. The supply of natural gas is then shut off, and the diffusion cycle begins.

The build-up of carbon in the steel follows the pattern shown in Fig. 1. At the end of the carbon input period, when the supply of carburizing gas is cut off, the carbon content of the steel is about as shown in Fig. 3. The diffusion period takes up approximately 4 hr., during which the concentration of carbon in the steel gradually diminishes at the surface layers and increases at the center of the section. Little additional carbon is added to the work during this period. The tendency toward equilibrium carries carbon from the carbon-rich surface layers, where an excess has been supplied during the carburizing period, toward the center of the piece. The distribution of the combined carbon gradually becomes homogeneous throughout the cross-section.

Equalizing action is speeded by increasing the temperature of the furnace during the diffusion cycle, and it is held at 1700 F during the 4-hr. period.

At the conclusion of the equalizing period, the furnace temperature is permitted to drop to about 1650 F over a half-hour interval, and the furnace is then opened and the work air-cooled to black heat. The air-cooling requires about 10 to 15 min. This completes the carburizing operation.

As has been pointed out, the steel formerly used gave rise to some difficulties in forming, and the finished product showed some nonuniformity from piece to piece, and in different areas of the same piece. Use of a low-carbon steel for the spring, and through-carburizing after forming, gave the following advantages:

(1) Certain extra costs in ordering the steel were avoided. It was no longer necessary to require cross-rolling of the stock to obtain uniformity in the finished piece. Also, ordering to finished thickness effected a slight saving in steel.

(2) Preliminary operations were omitted. Grind-

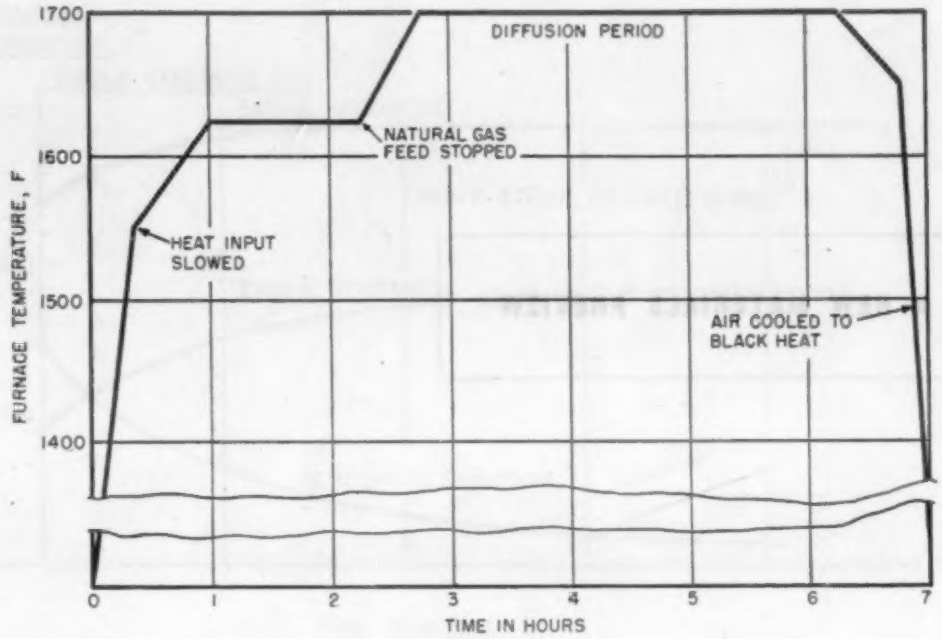


Fig. 2—Shown here is the heating and cooling cycle used in through-carburizing low carbon steel which is intended for spring use.

ing off the surface of the steel to eliminate decarburized skin after spheroidizing was unnecessary, so permitting the ordering of the steel to size.

(3) Forming was easily accomplished without anneals.

(4) The finished spring was more uniform in hardness. In addition to actual cost savings, a better product resulted.

(5) After processing conditions had been established, operating controls were not difficult. Only rates of gas flow and input of electrical energy are metered during operations.

In through-carburizing with the atmosphere held uniform throughout the cycle, the operation is essentially a prolonged case-carburizing. The carbon potential must be carefully adjusted in the atmosphere so that the carbon content of the steel will gradually rise to a value that will be in equilibrium with that potential. Because the carbon content of even the surface layers never rises above the value fixed upon for the final content of the steel, through and through, prolonged heating is needed to bring the center of the steel up to this percentage. Its advantage for work having nonuniform cross-sectional area has already been mentioned.

While the time required to build up the carbon content of a piece of steel to a given value must be determined for the particular piece, it will ordinarily require about one and one-half to two times as long as would be needed to build up a hardenable case to the same depth. The depth is, of course, half the thickness of the piece—not the total thickness. By using the second method, in which the carbon is rapidly built up in the steel from a strongly carburizing atmosphere and then diffused throughout the thickness of metal to obtain uniformity, this rate will depend upon the gradient set for the carbon, but will be substantially lower.

The practicability of the method has been demonstrated in industry. Its value, in making possible the fabrication of a part from thin low-carbon steel and then transforming the finished piece into medium- or high-carbon steel by a furnace treatment is obvious. It remains only for industry to find the proper applications.

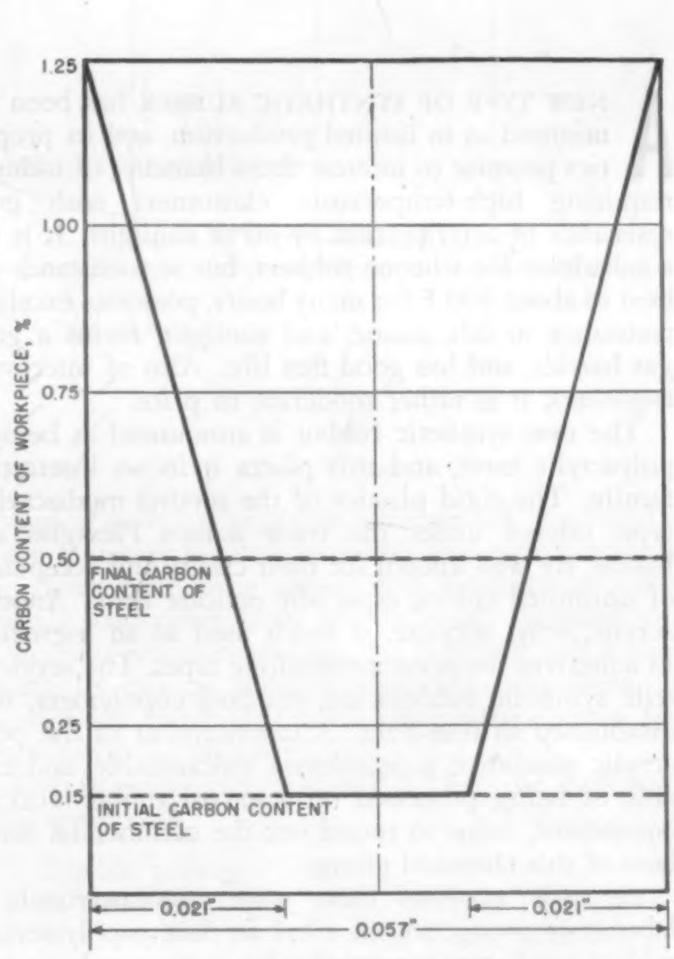


Fig. 3—The increase in carbon content of steel from 0.15 to 0.50% is a result of the new through-carburizing method.

A NEW MATERIALS PREVIEW

New Synthetic Rubber Has High Oil and Heat Resistance

A NEW TYPE OF SYNTHETIC RUBBER has been announced as in limited production, and its properties promise to interest those branches of industry requiring high-temperature elastomers with good resistance to deterioration by oil or sunlight. It is not a substitute for silicone rubbers, but it withstands dry heat to about 400 F for many hours, possesses excellent resistance to oils, ozone, and sunlight, forms a good gas barrier, and has good flex life. Also of interest to engineers, it is rather moderate in price.

The new synthetic rubber is announced as being a polyacrylic ester, and this places it in an interesting family. The rigid plastics of the methyl methacrylate type, offered under the trade names Plexiglas and Lucite, are well known for their clarity and acceptance of unlimited colors, especially delicate tints. Another acrylic, ethyl acrylate, is much used as an ingredient in adhesives for pressure-sensitive tapes. The acrylonitrile synthetic rubbers are standard copolymers, well established in that field. Announcement of the polyacrylic elastomer, pale colored, vulcanizable, and capable of being processed on standard rubber-working equipment, helps to round out the commercial members of this chemical group.

As early as 1944 there were announcements of laboratory production of ethyl acrylate copolymerized with a small percentage of other compounds to produce a rubbery material. Dr. C. H. Fisher, director of the Carbohydrate Section of Eastern Regional Research Laboratory of the Department of Agriculture, reported a little later upon an elastomer composed of 95% ethyl acrylate and 5% chloroethyl vinyl ether that was being studied in the laboratory. It was called Lactoprene EV because lactic acid was suggested as an intermediate in preparation of the material from several abundant carbohydrates. Chemists of the B. F. Goodrich Chemical Co. were working along the same lines, and developed the polyacrylic now being offered to industry under the name Hycar P.A. Both are in the same general family, and have such properties as high resistance to deterioration by heat, oil, and sunlight.

The properties of Lactoprene EV have been compared with styrene rubber GR-S, one of the popular synthetics, in the following table:

Lactoprene EV highly superior to GR-S in—

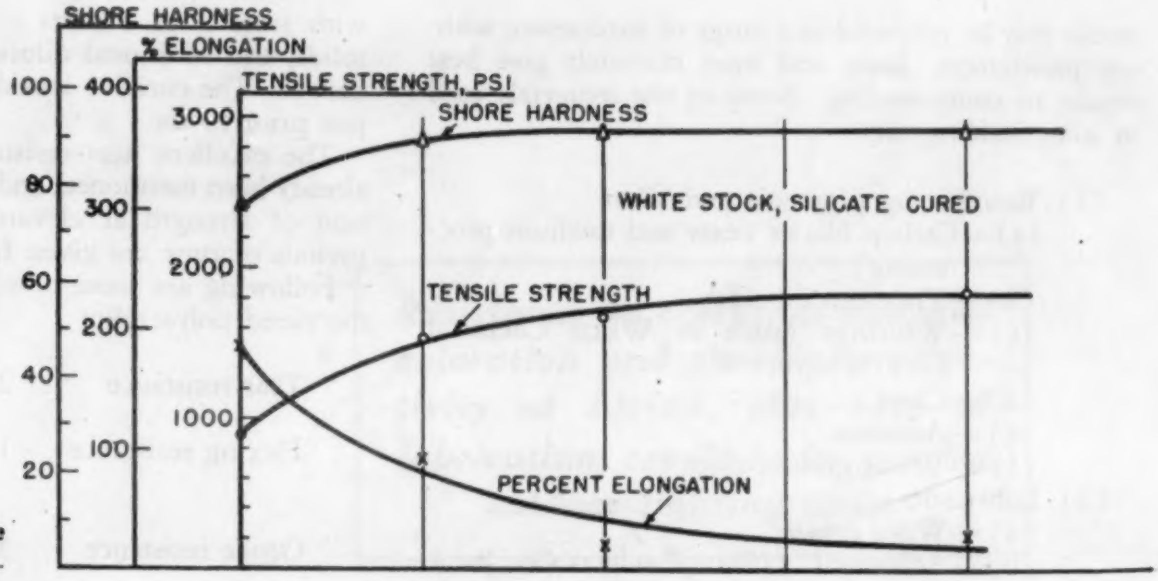
(1) flex life; (2) oil resistance; (3) resistance to oxidation and aging at normal and elevated temperatures; (4) resistance to sunlight.

Lactoprene EV superior or advantageous to GR-S in—

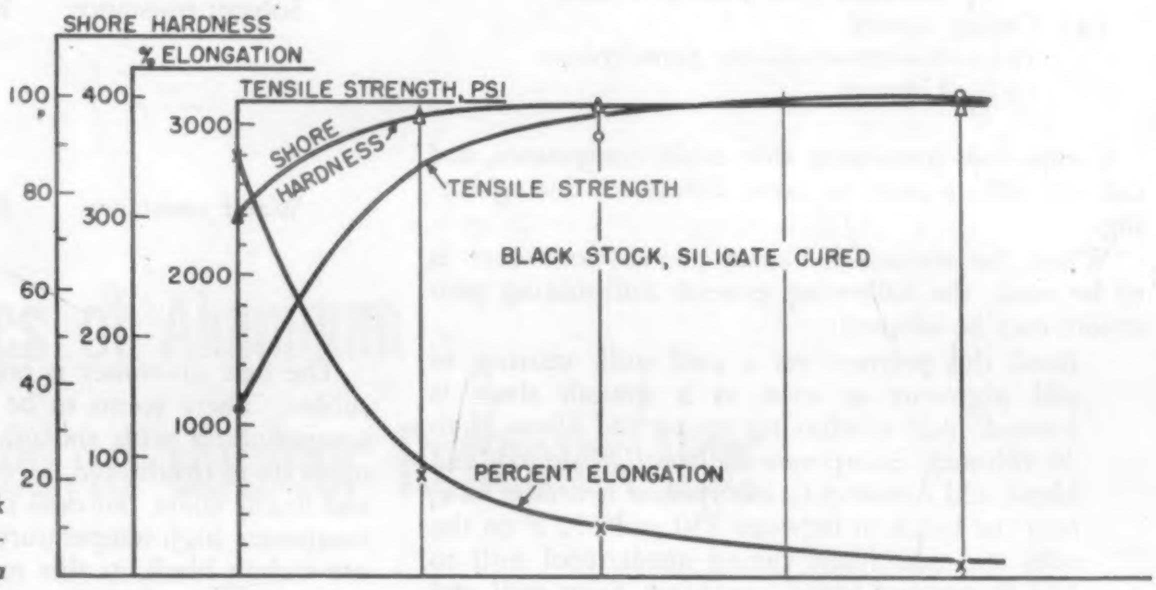
(1) permeability to helium, hydrogen, and carbon dioxide; (2) retention of elongation at high temperature; (3) abrasion resistance (data limited); (4) ease and simplicity of production; (5) yield from carbohydrate sources; (6) suitability for production of white stocks or articles made in pastel shades.

Lactoprene equal to GR-S with respect to—

(1) ease of incorporating pigment; (2) variety of curing recipes and rate of curing; (3) retention of tensile strength at 212 F; (4) permanent set; (5) resilience at 212 F.



Heat resistance of white polyacrylic stock, silicate cured at 300 F for time indicated.



Similar data for black polyacrylic stock, silicate cured. All data from B. F. Goodrich Chemical Co.

GR-S superior to Lactoprene in—

(1) tensile strength at normal temperatures (slight for similarly loaded samples); (2) retention of modulus at 212 F (except in the longer cures); (3) compression set (slight); (4) heat build-up (except for higher cures); (5) resilience at room temperature; (6) flexibility at low temperatures (but Lactoprene is sufficiently flexible, if plasticized, at temperatures normal in civilian applications); (7) resistance to steam; (8) swelling in water (this might be either advantageous or disadvantageous, depending upon the application); (9) cost.

A substantial lowering in the price of the monomer from which Lactoprene is produced has been predicted within the next several years, and there is reason to believe that this price differential could be reflected in a moderately-priced synthetic.

The polyacrylic rubber produced by Goodrich Chemical and now available commercially is offered as a dry material for compounding and vulcanizing, or as a latex containing about 50% total solids. Compounds may range from soft to hard. Patented vulcanization processes convert the polymer into a thermoset. It can be molded, extruded, calendered, or cured with standard rubber equipment, but a few precautions are necessary.

The unvulcanized Hycar P.A. has the following basic properties:

Specific gravity	1.1
Mooney viscosity	50-70 (approx.; determined after 4 min. at 212 F)
Appearance	light amber (resembles pale crepe rubber)

By varying the formulation to include more or less curing agent and/or during compounding, cured

stocks may be prepared in a range of hardnesses, without plasticizers. Basic and inert materials give best results in compounding. Some of the materials used in compounding are:

(1) Reinforcing pigments and fillers
  (a)—Carbon blacks (easy and medium processing)
  (b)—Titanium dioxide
  (c)—Whitings (such as Witco Chemical Co.'s Whitcarb R)
  (d)—Clays
  (e)—Asbestos
  (f)—Water-ground mica
(2) Lubricants
  (a)—Wool grease
  (b)—Acrawax C (Glyco Products Co., Inc.)
(3) Accelerators
  (a)—Hydrated lime (for sodium-m-silicate cures)
  (b)—Mixed ethyl and dimethyl mercaptothiazoles (for litharge cures)
(4) Curing agents
  (a)—Sodium-m-silicate pentahydrate
  (b)—Litharge

Compounds containing zinc, acidic compounds, and calcium silicate seem to cause difficulties during curing.

When the sodium-m-silicate pentahydrate cure is to be used, the following general mill-mixing procedure may be adopted:

> Band the polymer on a cool mill, starting to add pigments as soon as a smooth sheet is formed. Add reinforcing agents and fillers 25 to 30 volumes, incorporate the wool grease, cut and blend, add Acrawax C, incorporate hydrated lime, heat the batch to between 150 and 175 F on the rolls and add fused curing agent, cool mill to 100 F, cut and blend, cut batch from mill and weigh to check upon pigment loss, pass endwise through the mill six times at smallest opening, and sheet the batch from the mill at a thickness slightly greater than that of the article to be cured.

The litharge cure follows the same procedure, but the litharge is added at the beginning of the milling procedure, on a cold mill, and the organic accelerator is used instead of lime; however, litharge cured Hycar P.A. is not as heat resistant as sodium metasilicate vulcanizates.

Curing is done at about 1000 psi. or higher for compression molding, and for about 45 min. at 310 F for articles 0.10 in. thick. Thicker sections require slightly longer curing, but after 60 min. the curing curve flattens out.

The polyacrylic can be used as a cement or coating by compounding from the dry material without sodium metasilicate, and making up a dough or gel with a solvent composed of 90% methylethyl ketone and 10% ethanol by weight. Thin strips of the polymer are added to the solvent until the gel holds 30% solids by weight; 2 to 6 hr. rolling or agitation will be necessary to form the gel. The gel can be broken with from 1 to 2 parts of water, based upon total solids, and additional diluting water can be added if desired. The curative is added as an aqueous solution just prior to use.

The excellent heat resistance of the elastomer has already been mentioned, and curves showing the retention of strength at elevated temperatures for long periods of time are given from additional data.

Following are some other interesting properties of the cured polyacrylic:

Tear resistance	250 to 300 psi. in crescent tear (white stock).
Flexing resistance	15 to 18 million flexions without failure (carbon black stock).
Ozone resistance	500 hr. at concentrations that crack rubber in a few min.
Gas barrier	Twice as impermeable as rubber to air, nitrogen, hydrogen, oxygen.
Solvent resistance	Excellent to heavy oils, kerosene, cottonseed oil, glycerine, mineral oil, and fats. Not resistant to alcohol nor to solvent esters.
Water resistance	From poor to fair, depending upon compounding. Litharge-cured stocks superior to silicate stocks.

The new elastomer is not compatible with natural rubber. There seems to be nothing to be gained by compounding with the other synthetics. When the material is overheated, it overcures, becomes brittle, and finally chars, but does not melt. Formulations for maximum high-temperature applications should not use carbon black, as this tends to reinforce the cure.

Most proposed and present uses take advantage of the elevated-temperature resistance of the material. The resistance to deterioration by sunlight makes it a valuable coating for paper or cloth; high-temperature gaskets, requiring heat and oil resistance, might use asbestos or glass fiber fabric. Before cure, the solvent or latex preparations form useful adhesives. Insulated wire for electric ranges, and for jet aircraft, as well as electric motors, will form another possibility. Brake linings have been suggested also.

While the acrylic is not recommended for continuous service at temperatures above 250 F, nor for intermittent exposure above about 400 F, it has been used occasionally where its life, even if short, is still economical in comparison to other materials. A wiper for tin plate, removing the excess molten tin from sheet at 550 F, was made of the new synthetic. It lasted for 10 hr. at this temperature, and the users decided it was preferable to the previous installation, using wood blocks, with a life of only 3 hr.

Present prices somewhat higher than $1.00 per lb. will keep the polyacrylic rubber in the specialty class, but its properties assure it of a place in that class, and if lower prices can be attained in the future with increased production, its scope will be widened.

Resistance to corrosion and discoloration and the high reflectivity of Alclad, plus ease of fabrication, result in its use for outdoor lighting units.

Characteristics of Aluminum Make It Suited to Outdoor Reflector Use

by W. IRBY, General Electric Co.

THERE ARE MANY FACTORS which enter into the selection of a reflecting surface for outdoor lighting. The amount of light produced by a unit as well as the distribution is dependent in part on the reflectivity and physical structure of this surface. Such factors as wind, weather resistance, chemical and electrochemical corrosion, solid and gaseous content and humidity of air and operating temperatures are all factors that play an important part in the selection of the proper material.

The ideal outdoor reflecting material should have the following characteristics:

1. A satisfactory initial co-efficient of reflection.
2. Ability to maintain its reflectivity in service.
3. Ease and economy of fabrication.
4. Sufficient rigidity to maintain original shape and contour.
5. Resistance to heat.
6. Resistance to a cleaning material.

Many reflecting surfaces have been used over the years to meet one or more of these requirements. With the development of a satisfactory finish for aluminum, however, this metal has become the most widely accepted in the manufacture of outdoor lighting because it brings it so close to the ideal.

This new finish, known as the "Alzak Process," when applied to an aluminum surface not only reflects more light, but also makes an aluminum surface more permanent and weather resistant than ever before. This process was announced by the Aluminum Co. of America some ten years ago and applied to outdoor lighting units after very thorough tests were made jointly by Alcoa and the General Electric Co.

During the past eight years, lighting engineers have been intensively working with Alzak finished aluminum and have developed street, highway, bridge, tunnel, and floodlight units, which are more efficient, and at the same time less costly than during any former period in the history of the industry.

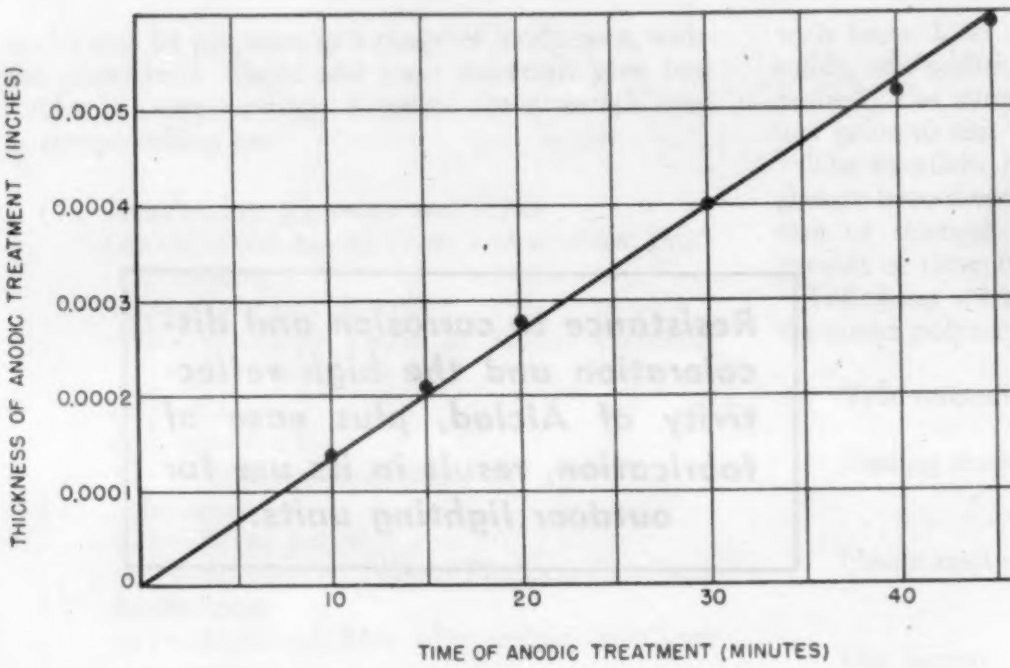


Fig. 1—Thickness of anodic film versus time of treatment (one side only).

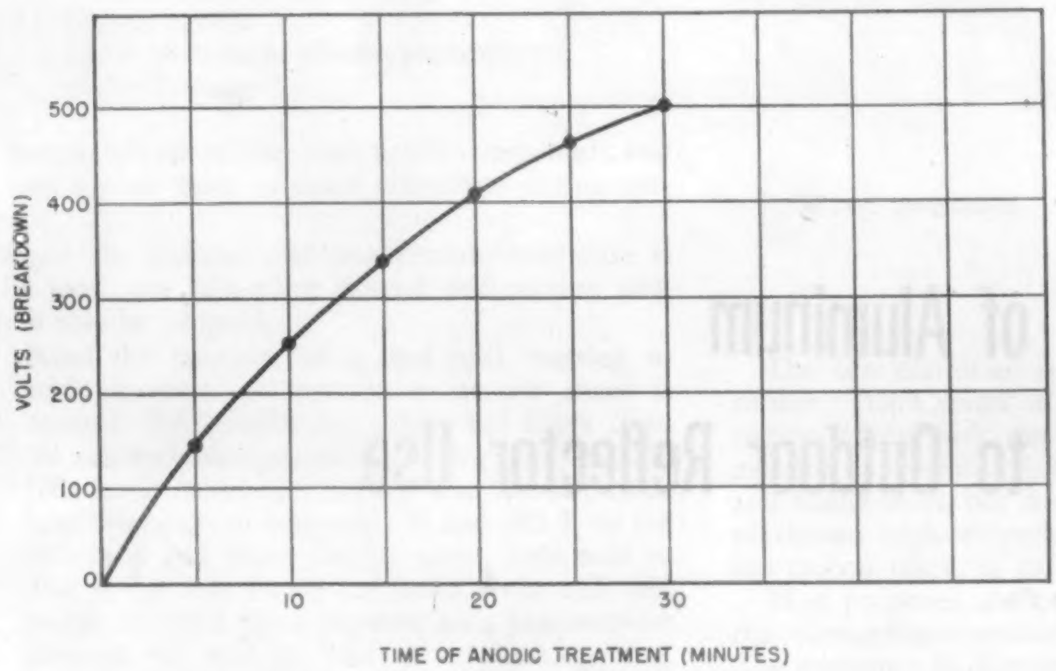


Fig. 2 — Time of anodic treatment versus breakdown voltage. (Breakdown taken through anodic film on both sides of sample.)

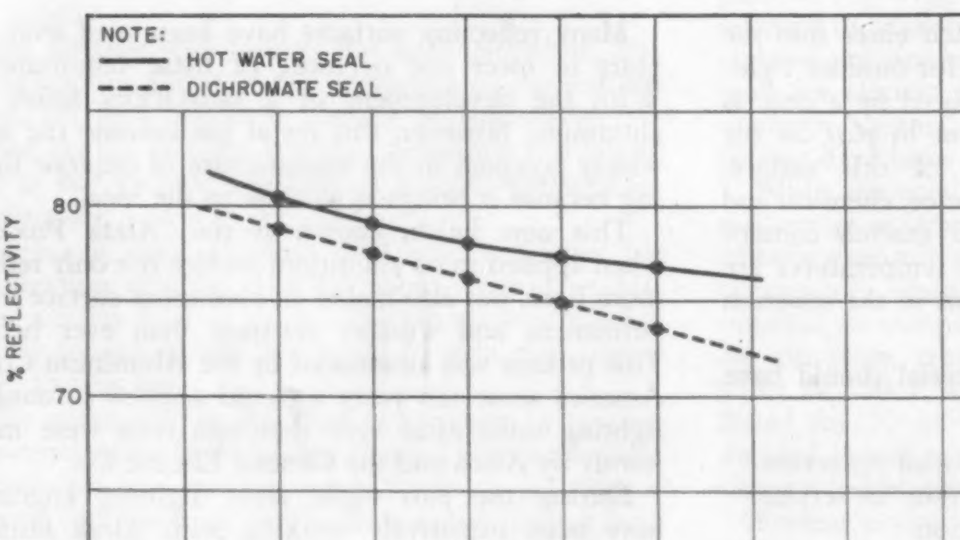


Fig. 3—Percent reflectivity versus time of anodic treatment for specular finish.

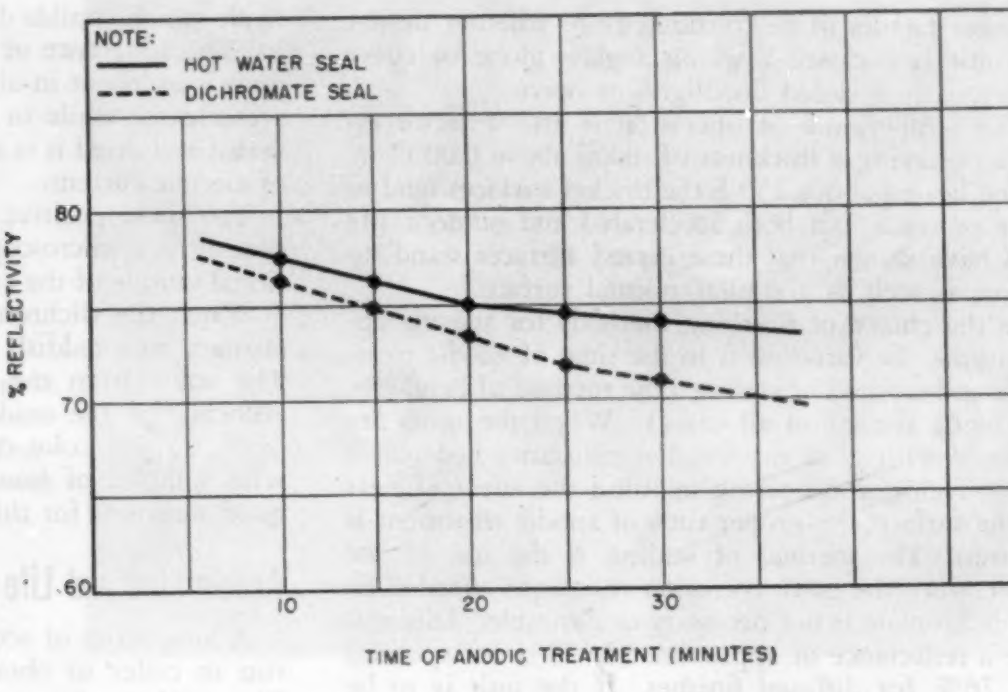


Fig. 4—Percent reflectivity versus time of anodic treatment for diffused finish.

Choice of Sheet Aluminum Stock

The best sheet aluminum for lighting units is Alclad stock. This material has a layer (15% of total thickness) of almost pure aluminum on the reflecting side, while the body (85%) is made of #2S alloy consisting of approximately 99% aluminum; the alloying materials, which are small amounts of copper, manganese and iron, aid in the working properties of the stock. They also improve the strength of the final product. This "two-layer" material is so made that it fabricates and otherwise behaves as a single-layer material. Since pure aluminum has a much better reflectance as well as improved weather resistance compared to an alloyed material, it has been found distinctly advantageous to use this stock for all lighting units whether a specular or diffused finish is desired. Although there is a special alloyed one-layer stock, which is used in some cases for diffused units, our experience has shown the "Alclad" material to be superior in both reflectance and life in service and is used in all cases for outdoor reflectors.

In way of explanation, reflectance or reflecting factor is a term used to measure the efficiency of a surface, and it is the ratio of the total light reflected from a surface to the total light falling upon it.

The amount of "glossiness" or specularity should not be confused with reflectance as the latter is a function of the metal itself; for example, a diffused Alzak aluminum surface, when properly prepared, has much better reflectance than a specular mirror-like surface.

The Alclad sheet aluminum stock (for example, 0.040 to 0.060 in. in thickness, dependent upon conditions) is spun or drawn to form the desired reflector unit; the Alzak finish is then applied as follows:

A specular surface is one which has a mirror-like reflectance. A beam of light is reflected from it without appreciable diffusion or scattering of light. This surface is obtained by: (1) buffing; (2) cleaning by vapor degreaser; (3) electrolytic brightening by anode which removes metallic impurities; (4) anodically treating in a sulfuric acid solution to change the surface from aluminum oxide; (5) "sealing" by an immersion in either hot water or a hot dilute solution of potassium dichromate; and (6) dried.

A diffused surface is one which scatters or diffuses the light in all directions. This surface is obtained by: (1) cleaning; (2) etching or "roughening" in a hot caustic soda solution which contains sodium fluoride, and dipping in concentrated nitric acid (to remove metallic impurities left on the surface); and (3) rinsing and then putting through the Alzak process (brightened, anodized, and sealed) exactly as described above.

The electrolytic brightening materially increases the reflectivity of the aluminum while the anodic treatment decreases it somewhat, but the latter process greatly increases the weather resistance. The sealing operation also increases the weather resistance, in that the oxide form is changed from a non-crystalline to a crystalline condition; in this process the surface is sealed and becomes non-absorptive of foreign materials. Potassium dichromate is absorbed from solution, when the second sealing method described above is used. This chemical absorption acts as an additional inhibitor to corrosion. The relation of time of anodic treatment, thickness of oxide layer formed, and change in reflectivity is given in charts below.

Variation in Finishing Process for Different Applications

Since time of anodic treatment affects reflectivity and life in service, the anodic treatment as well as the sealing process depends on the application of the unit involved.

Other factors to be considered are whether or not the unit is enclosed (having a glass globe or cover glass), as in a closed floodlight, or open.

The temperature of operation is also a factor on surfaces having a thickness of oxide above 0.0002 in. When heated above 250 F the thicker surfaces tend to craze or crack, but both accelerated and outdoor life tests have shown that these crazed surfaces stand up almost as well as a similar normal surface.

In the choice of finishing methods for specific applications, the variation is in the time of anodic treatment and method of sealing (the method of brightening being similar in all cases). When the units are enclosed with glass the weather resistance becomes a minor factor, and bearing in mind the effect of heat on the surface, the proper time of anodic treatment is 15 min. The method of sealing is the use of hot water, since the extra corrosion resistance afforded by the dichromate is not necessary or desirable. This will give a reflectance of approximately 79% for specular and 76% for diffused finishes. If the unit is to be open (not covered with glass) heat resistance is not a factor but weather resistance is. In this case, the time of anodic treatment is 30 min. and the dichromate sealing method is used. In the latter case reflectance has been somewhat decreased, but it is a small sacrifice to make in view of the great improvement gained in weather resistance.

In the case of sodium units and open suburban reflectors, the surfaces are given an additional "plastic seal," that is, they are coated with a clear synthetic varnish, after the Alzak process has been applied. This seal is a clear, hard drying lacquer of high light transmission quality and an excellent weather resistor. The life of the Alzak reflecting surface is greatly increased from the use of the "plastic seal."

Nature of Finish

It has been stated above that when the aluminum unit is made anode in the sulfuric acid solution that the surface of metal itself is changed over to the oxide. It will be noted that this is quite different from an electroplating procedure wherein the work is made cathode and is "built up" with some plated metal. When aluminum is anodized, oxygen is plated on its surface and the material is converted to aluminum oxide which "builds down" or works from the outside in. The adherence of the oxide to the mother aluminum is excellent in all cases. This aluminum oxide is a conductor while in the solution, but when washed, sealed and dried it is an excellent insulator to the flow of electric current.

The most positive test of thickness of the oxide coating is a microscopic measurement of a cross sectional sample of the coated material.

When the dichromate finish is used the color is changed to a reddish yellow resembling that of brass. The color from the dichromate sealing solution is absorbed by the oxide in proportion to thickness of oxide, so that color of product can, and is compared with samples of known thickness. This is a rather good shop test for thickness of coating.

Accelerated and Life Tests

A long series of accelerated and life tests have been run in order to obtain the results described above. The accelerated tests were made in salt spray, steam chest, and humidity chamber; while life tests were made in marine, industrial, and rural areas. These tests have shown the worst conditions to be warm humid atmospheres for accelerated tests and industrial areas for the service tests.

Below is a summary of tests conducted by the Aluminum Co. of America in cooperation with the General Electric Co., which covered a period of 3 years. These tests were made on flat surface reflectors exposed at angles of 45 deg. with reflecting surface up. The tests were made under marine and industrial conditions. It will be noted that the reflectivity values are somewhat higher than those shown on charts but data are comparative.

These tests as well as others have shown that flat surfaces, when in a vertical position, collect less dirt and water, by condensation, than horizontal or semi-horizontal surfaces; and that smooth or specular surfaces, in any position, corrode more slowly than diffused surfaces. Rain-drops or condensed water collect on the underside of horizontal surfaces; this water absorbs gases in industrial areas forming dilute acid solutions which slowly corrode and pit the aluminum. Collection of dirt accelerates this action, so that removal of dirt and corrosion products from the surface retards corrosion.

Type Reflector			Reflectivity—%			
			After 3 Years' Exposure at Seashore		After 3 Years' Exposure at New Kensington	
Surface	Approx. Thickness of Coating in In.	Orig.—No Exposure	% Reflectivity (After Cleaning)	% Loss	% Reflectivity (After Cleaning)	% Loss
Specular	0.0001	85.5	82.5	3.0	82.5	3.0
Specular	0.0002	84.5	82.5	2.0	82.5	2.0
Specular	0.0003	84.5	83.0	1.5	82.5	2.0
Diffusing	0.0001	80.5	77.0	3.5	73.0	7.5
Diffusing	0.0002	71.5	70.0	1.5	64.5	7.0
Diffusing (dichromate seal)	0.0001	78.5	75.0	3.5	75.0	3.5
Diffusing (dichromate seal)	0.0002	76.0	73.3	2.7	70.5	5.5

A group of typical parts metal-coated by the vacuum deposition method. (Courtesy: National Research Corp.)

Metal-Coated Plastics Combine Advantages of Both Materials

by H. R. CLAUSER, Associate Editor, Materials & Methods

There are many applications in which it is desirable to use a combination of metals and plastics. By proper design and careful selection of the metal and plastic it is often possible to capitalize on the strong points and minimize the weaknesses of each and thereby secure a combination of service properties that could not be obtained if one or the other were used alone. Metal inserts and inlays have long been used as a means of extending the uses of plastics. More recently, metal coating of plastics has come into the picture and is now being extensively used not only in the decorative field, but also for a wide range of practical and industrial products.

There are many reasons for taking advantage of metal-coated plastics. One important reason is that it is possible to combine the advantages of light weight and ease of fabrication in plastics with certain desirable characteristics of metals. For example, the tensile and impact properties of plastics can be improved by a metal coating. In many instances, the strength has been improved anywhere from 10 to 30%. In addition, flexural properties and abrasion resistance can often be improved.

A characteristic which sometimes limits the use of plastics is relatively low heat resistance. This is particularly true of thermoplastics. A metal coating helps to dissipate heat and thereby raises the service temperature at which a part will begin to deform. Where conditions of localized heating are encountered, the metal coating serves well as a heat dissipater. Even where temperatures high enough to cause distortion in the plastic are not encountered, a metal coating can often increase the dimensional stability of the part.

Metal coatings extend the use of plastics to a variety of tasks where electrical conductivity in the

Metal coatings, applied to plastics by three different methods, provide special combinations of properties to meet both engineering and decorative needs.

part is required. Recently developed "printed circuits," in which a coating of silver or copper on plastic serves as the wiring in electronic apparatus, is perhaps the most spectacular example. But there are many other applications that are probably more typical, such as airplane antenna masts, high-frequency wave guides used in radar equipment, and contacts for electrical leads.

When metals are plated on metals, the part is often susceptible to corrosion by electrolytic action between the metal coating and the base metal. This electrolytic corrosion is not possible where a metal coated plastic is involved. For this reason, the corrosion resistance of a given metal plated on a plastic is generally superior to the same metal plated on a metal base. This creates many potential uses for metal-coated plastics in the chemical and food industries and for such uses as outdoor hardware.

Finally, metals are better light reflectors than plastics and can be used to advantage in the production of plastic mirrors both for decorative and industrial applications.

There are a number of different methods for metal coating plastics. Only the three that are most widely used will be discussed here; they are (1) electroplating, (2) vacuum deposition, and (3) metal spraying.

In coating plastics with metals whatever method is used, adhesion is probably the most important single factor to consider. Metals and plastics have no "natural" adhesion for each other. The fact that the difference in expansion between metals and plastics is quite great further complicates the adhesion problem. Consequently, special pains must be taken to provide for a good bond. The first step is to obtain an absolutely clean surface, and then in most cases follow this with a mechanical or chemical treatment. Adhesion can often be improved by careful design. Wherever possible, grooves or indentations, mechanical interlocks, re-entrant curves, and finally, rounded instead of sharp edges and projections should be provided.

Electroplating Methods

In the electroplating method there are two major steps: (1) application of a conductive layer or layers; (2) electrodeposition of one or more layers of metal on the conductive undercoat.

Before putting on the conductive coating it is often necessary to seal the plastic surface with a wax compound or a varnish of some kind to improve adhesion. Adhesion is also improved by roughing or etching the surface. This can be done mechanically by tumbling or blasting with an abrasive, or chemically by various means such as treatment with oxidizing acids or caustic solutions.

Besides providing a conductive layer to carry the current during the subsequent electroplating operation, the undercoat has the function of providing a bond between the metal coating and the plastic base. Thus, it must be strong enough and have sufficient elasticity to withstand differences in expansion between the plastic and metal coating.

There are many different types of conductive coatings that can be used. The oldest method involves a wax coated with graphite. However, it gives a coating of relatively low conductivity and lacks good adhesion properties. Where a simple one-step method is desired, a lacquer or varnish usually containing a copper or silver powder is applied by brushing, dipping or spraying.

A chemical reduction method in which a layer of silver is deposited from a chemical solution is one of the most widely used. The application can be accomplished by dipping the plastic part in a tank of the reducing solution, or by spraying. In the spraying method, the chemical reduction takes place in the spray gun reservoir; the metallic silver in a suitable vehicle is thus sprayed on the part.

Although the chemical reduction method's primary use is to supply conductive coats for electroplating, it is also used by itself for certain applications, such as silver coating of glass or plastic base mirrors and more recently for producing printed circuits.

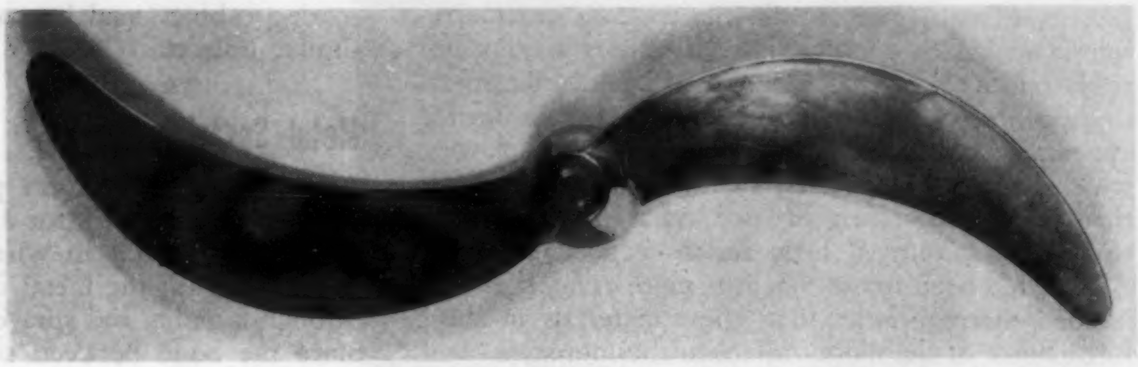
There have been a number of formulations developed in attempts to obtain a satisfactory layer of copper by reduction from chemical solution, but they have not generally proved commercially feasible. However, within the last year a new process has been reported that involves the production of copper film followed by another layer of either copper or silver. It involves the reduction of copper from a Fehlings solution with a metalloorganic derivative of sodium hydrosulfite. The process is reported to be cheaper than silvering and to produce a thicker film with better adhesion.

Another widely used means of making plastics conductive is to apply a rubber composition. This method is used extensively for large industrial products because it offers a strong, elastic bond and can be used in varying thicknesses to obtain the bond strength required. The coating can be applied by spray, dip, or brush methods. To provide electrical conductivity, a conductive rubber can be used, or the coating can be given a surface treatment with a conductive material such as bone black.

Electrodeposition of the finish layers of metal on the conductive undercoat in general follows standard electroplating practice. Since the conductive coat is usually thin, high current densities must be avoided for the initial layers. Also, since the conductive coating is likely to be porous, high acid or alkaline baths cannot be used on all plastics. Finally, where thermoplastics are involved hot plating baths and dipping in hot water must be avoided.

Any metal that can be plated on metal can also be plated on plastics. For heavy deposits iron, copper and nickel are generally chosen. For decorative coatings nickel, brass, gold and silver are probably the most widely used.

The range of possible coating thicknesses is very wide. With flash treatments, films as thin as one-millionth of an inch are reported; for industrial products thicknesses from about 0.002 in. up. There is no definite upper limit of thickness; some plastic parts have been plated with ⅜- to ¼-in. metal coatings.



This industrial fan blade is made of a phenolic plastic with a 0.002- to 0.005-in. plating of nickel. Left, the uncoated plastic; right, after plating. (Courtesy: United States Rubber Co.)

The size of plastic parts that can be electroplated is only limited by the size of the available equipment. For example, propeller blades approximately 5 ft. long and helicopter tail rotors have been successfully electroplated using a rubber-composition conductive coating followed by nickel plating.

Parts with flat, regular, external surfaces are generally most satisfactory for plating. Irregular and hollow shapes, however, can also be plated as long as the depth does not exceed the width of the opening; otherwise, conforming anodes are required.

The characteristics and properties of electroplated metals on plastics are the same as those of metal platings on a metal base. The smoothness of the finish generally depends upon the finish of the plastic surface. When using a rubber-composition undercoat it has been found possible, however, to produce a finish smoother than the base plastic.

The varied applications of plated plastics are too numerous to mention in detail, but here are a few typical ones:

Small commutator for a radiosonde for weather forecasting—A silver coating, 0.008 in. thick, is plated on a grooved rectangular plastic strip after which the silver is machined off, leaving thin strips of silver in the grooves.

Wave guides for radar—On one type, 0.002 in. of silver and then a gold flash is placed on a styrene base.

Antenna masts for airplanes—A 0.012-in. copper or iron coating over pressed resin impregnated plywood.

Fan blades—A typical example is a fan blade made of Bakelite and plated with 0.002 to 0.005 in. of nickel.

Vacuum Evaporation

There are two high vacuum techniques for depositing metals on plastics: cathode sputtering and vacuum evaporation. Cathode sputtering is the older of the two. In this method the plastic to be coated is placed in a vacuum chamber close to a metal anode. The metal to be deposited serves as the cathode. When high voltage is applied to the circuit, metal atoms in the form of ions leave the cathode and are deposited on the plastic part. This technique is rather slow and tedious and has limited application as compared to the vacuum evaporation method.

In the vacuum evaporation method the metal is heated to its evaporation temperature in a vacuum chamber by means of an electric filament. The metal evaporates and condenses on the plastic surface. Usually the work chamber is evacuated in stages. In the first or "roughing stage," a mechanical pump evacuates down to 100 to 200 microns of mercury. The evacuation is then continued down to about 0.1 micron. (1 micron equals 0.001 mm.) of mercury using a diffusion pump. This evacuation process takes about 10 to 20 min., depending upon the type and size of the apparatus. The metal evaporation process requires about 1 min.; this time varies, of course, depending upon the thickness of film deposited. Another minute is required to release the vacuum.

The work can be processed by batch or continuous methods. In batch units, the plastic parts are usually held in jigs at 12 to 24 in. from the filament. Various size vacuum chambers are available, a typical one for industrial products being 48 in. long and 48 in. in dia.

Continuous units are used largely for sheet materials that can be rolled while being processed. The uncoated stock is placed on a roll in the chamber, is unrolled slowly, and passes over the metal evaporation area, after which it is taken up on another roll. Zoned vacuum equipment is now also available for continuous processing. Through ingenious design of interconnected compartments the parts move through compartments having successively higher vacuums to the metal evaporation chamber. After being coated the parts pass out through lower vacuum compartments. Where suited to the application, continuous vacuum units eliminate the need of evacuating and releasing the vacuum for each batch of parts. In many cases such an arrangement lowers total processing time considerably. For example, plastic mirrors, 24 by 24 in., are coated at the rate of one a minute using zoned vacuum equipment.

Practically all the common metals can be coated by the vacuum evaporation technique. Aluminum, silver, gold, zinc and copper seem to be most widely used. Although very difficult to do, some alloys can also be deposited by the process. This is accomplished by evaporating the alloying elements simultaneously. A simpler method is depositing the elements in successive layers and then alloying them by heat treatment.

Not all plastics can be successfully coated by vacuum methods. Plastics in which there are contaminants, large amounts of plasticizer, or absorbed moisture are difficult to process. Under vacuum these undesirable ingredients evaporate. In order to remove them, the time required to evacuate the chamber must be

increased; with some plastics the increase in time required makes this impractical. If vapors are not entirely removed, they may be trapped under the metal coating; this causes poor adhesion and gives a burned appearance to the coating. In general, thermoplastics, which contain plasticizers, are more difficult to coat than the thermosetting plastics. As a rule thermosetting plastics "outgas" little and have good adhesion. Also, it has been found that it is more difficult to coat molded thermoplastics than these materials in sheet form. Some of the more important thermoplastics that can be metal-coated successfully by vacuum evaporation are molded and cast Plexiglas and Lucite, cast nylon, polystyrene, and some of the cellulosics.

The vacuum deposition techniques are most suitable for obtaining very thin coatings of metal on plastics. Films as thin as 4-millionths of an inch are possible. The range of thickness generally worked with runs from 2-millionths of an inch up to about 0.0001 in. Although it is possible to deposit thicker layers than this, such is seldom done because the increased processing time makes it impractical.

The metal coating, because of its thinness, follows to less than one-millionth of an inch the finish of the plastic surface on which it is placed. The films are usually rather opaque, but semi-transparent films can also be obtained. Although these extremely thin coatings will not withstand scratching and heavy wear, they do have enough abrasion resistance to withstand some handling and light wear. For example, vacuum evaporated coatings have been successfully used at a contact surface on certain flat commutator parts.

The shapes of plastic parts that can be coated is limited by the fact that in the evaporation process the metal atoms travel in a straight line from the filament, so that only surfaces in the path of the evaporated metal will be coated. Thus, flat objects are best suited to the process. Rounded forms such as cylinders or spherical objects and concave or convex shapes can be handled by rotating them in the chamber. Where rigid parts are involved the size that can be coated is limited by the size of the work chamber; non-rigid materials, such as sheet, however, can often be coated continuously and thus increase the size capacity.

The vacuum deposition process is applicable to both engineering and decorative uses. A large portion of the industrial applications are in the electrical and electronic field. Radio components such as capacitors and resistors are made by coating mica with silver, or paper with zinc or aluminum. One of the advantages of such coated components is that they are made self healing. Should a break occur, heat causes the metal to volatilize around the puncture and thus prevents shorting of the circuit.

Other applications in the industrial field include coating front surface mirrors for television receivers with aluminum; applying either silver or aluminum to reflectors of infra-red lamps; placing silver on quartz crystals to provide a base for soldered contacts; and producing printed circuits.

In the decorative field probably the largest applications are metallizing decorative plastic sheets and plastic mirrors. The process is also adapted to metal coating cabinets and housings, nameplates, signs and similar objects.

Metal Spraying

In spraying metal on plastics the same general practice that is used for spraying metals on metals is followed. Metal in wire or powder form is fed through a gun; the metal is volatilized upon passing through a flame, and sprayed onto the plastic surface. Since the bond between the sprayed metal and the plastic is a mechanical one, it is necessary to roughen the plastic surface by blasting or by some other method such as treating the surface with a special lacquer.

Any plastic whose surface can be properly prepared is suitable for metal spraying. However, spraying of thermoplastics is generally limited to low melting point metals, since thermoplastics are susceptible to softening and distortion at relatively low temperatures.

Any metal available in wire or powder form can be sprayed on plastics. In general, a low melting metal, such as zinc or aluminum, is applied first, followed by layers of the desired finish metal.

The minimum thickness of coating that can be obtained by metal spraying is 0.001 to 0.002 in. There is no maximum limit. Any number of layers of sprayed metal can be applied, but film thicknesses of approximately 1/32 in. are commonly used. Since the structure of sprayed metal is inherently coarse, care must be taken to avoid porous, brittle coatings. Specific gravity of sprayed metal is 10% lower, in some cases, than the specific gravity of the same metal in other forms. Because of its porous structure the finish of sprayed coating is rougher than those produced by plating or vacuum deposition.

Spraying of conductive films on insulating surfaces is probably the largest use of this method. In addition to being sprayed on plastics, molten metal can be sprayed on wood, glass and ceramic surfaces. High voltage insulators have long used metal-sprayed coatings in order to distribute the electric field properly over the surface. Helical resistors for electric heaters are produced by a metal spray gun mounted on the carriage of a lathe that sprays a helix on a ceramic tube, using the thread cutting device of the lathe. For producing printed circuits, several ingenious methods utilizing metal spraying techniques have been developed. The spray method is popular for this work because it is fairly easy to adapt to production line practice.

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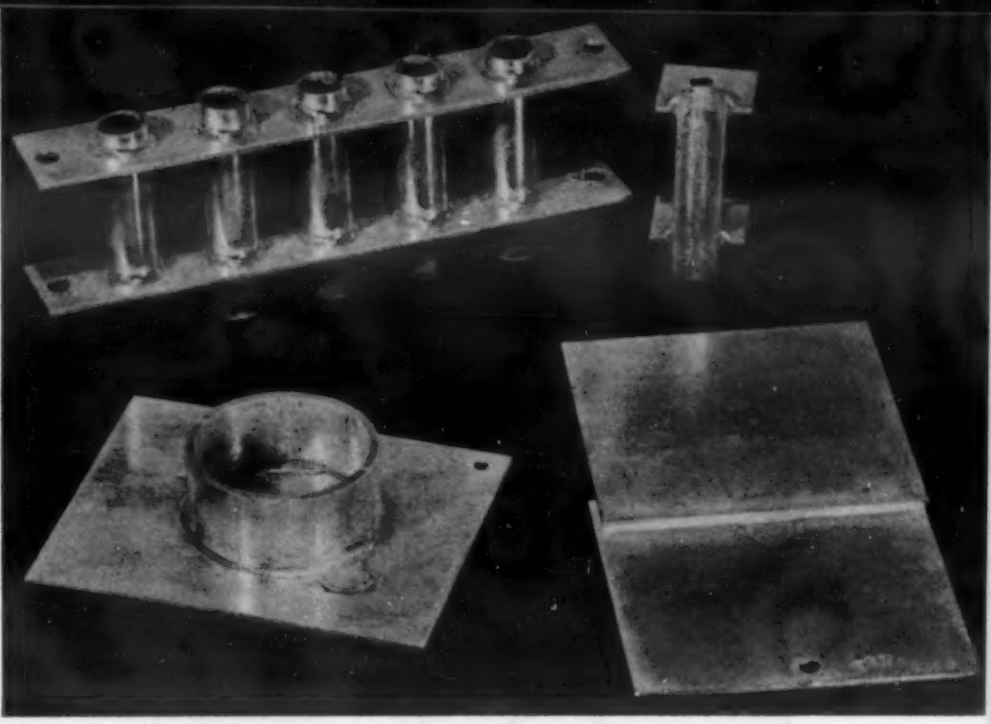


All of these magnesium parts have been furnace brazed by recently developed methods.

Economical Joining of Magnesium Possible Through New Brazing Method

by PAUL KLAIN, Metallurgist, The Dow Chemical Co.

A METHOD OF JOINING magnesium alloy parts by brazing has been developed to a commercial stage at the Magnesium Laboratories of The Dow Chemical Co. The new development offers possibilities for rapid and economical joining of magnesium alloy parts. At the present time, commercial brazing is limited to parts made of M1 alloy (Magnesium +1.5% manganese).

Brazing is a well known and well established joining method for most ferrous and nonferrous metals. For example, steel parts can be brazed with copper, brass, or bronze. Many ferrous and nonferrous alloys are also brazed with silver alloys. The aluminum alloys, however, are brazed with aluminum base filler alloys. The brazing of aluminum is relatively new, having been in use commercially only since about 1940 (see MATERIALS & METHODS, May 1948).

Practical production brazing of magnesium through torch, furnace and dip methods widen the possibilities of applying this metal.

The magnesium alloy brazing process which is about to be described is similar to aluminum brazing since magnesium base filler alloys as well as chloride base fluxes are used.

Brazing is a method of joining metallic parts by heating below the melting point of the parts to be joined but above the melting point of the brazing or filler alloy. The filler alloy melts and flows, usually by capillary force, into and around the joints. A flux or an active atmosphere is required to clean and protect the surfaces and to allow wetting of the parts by the filler metal for good flow and bonding.

Brazing Methods

Magnesium alloy parts can be brazed by the furnace, torch, and flux dip methods. In furnace brazing, the parts to be joined are usually assembled in jigs, with the brazing alloy preplaced around the joints. The joints are fluxed and then heated in the furnace at the desired temperature for a required time. Torch brazing is similar to gas welding except that little or no melting of the base metal occurs. In flux dip brazing, the assembled parts with preplaced brazing alloy are dipped into a molten flux bath held at the required temperature. Two other methods widely used in the brazing of other metals are induction and electric resistance heating. These have not yet been tried in magnesium brazing but should be readily useable.

Table I—A Summary of Factors Involved in the Brazing of Magnesium Parts

Brazing Item	Brazing Methods		
	Furnace	Torch	Flux Dip
1. Alloy Brazed	M1 Sheet and Extrusion	M1 Sheet and Extrusion	M1 Sheet and Extrusion
2. Brazing Alloy	AZ92 + 0.002% Be (min.) AZ125 + 0.002% Be (min.)	AZ125	AZ92
3. Temperature	1130-1160 F	——	1120-1130 F
4. Flux	Dow 451 Dow 452	Dow 450 Dow 451 or 452	Dow 450 Dow 451 or 452
5. Flux Application	Dry flux powder Chlorbenzol paste	Dry flux powder Alcohol paste	——
6. Preparation of Materials	1. Mechanical—Abrasion with steel wool or abrasive paper 2. Chemical—Degrease + 2 min. in Dow Bright Pickle Solution		
7. Cleaning Joints	Hot water + 1-2 min. Dow No. 1 Treatment + 2 hr. in boiling 5% sodium dichromate solution		
8. Types of Joints	Lap and fillet	All types	Lap or fillet with recessed grooves for retaining filler alloy
9. Clearances	0.004-0.010 in.	0.004-0.010 in.	0.004-0.010 in.
10. Strengths of Joints	14,000-16,000 psi.	18,000-23,000 psi.	14,000-16,000 psi.
11. Brazing Equipment	Electric or gas fired furnaces. Control within ±5 F	Oxyacetylene Air-natural gas	Electric or gas heated pot settings

The essential factors necessary in each of the three brazing methods—furnace, torch, and flux dip—are summarized in Table I. These factors will be covered in detail later.

Alloys

As already indicated, commercial brazing is limited to M1 alloy. The wide freezing ranges and the extremely low solidus temperatures of most of the other commercial magnesium alloys make it very difficult to find a suitable filler alloy, since the melting and flow points of the filler alloy must be below the solidus temperature of the parts to be brazed to avoid partial melting and possible burning. This may not hold true for torch brazing, but the usefulness of the filler alloy then becomes very specialized. In the case of cast alloys which cannot be heated much above 700 F, torch heating may be the only way of brazing them to other parts, since heating below 700 F would require filler alloys of the solder type.

Of commercial wrought alloys, only M1 and AZ31 have sufficiently high solidus temperatures for true brazing. For practical purposes, M1 cast shapes can be considered as having no freezing range. In wrought material small percentages of calcium are present. The calcium is generally added in amounts of about 0.1% to improve the fabricating characteristics. With 0.1% calcium, the solidus of M1 is reduced to about 1180 F. Therefore, it is perfectly safe to heat M1 near 1180 F for short periods of time without danger of burning unless other impurities which reduce the solidus still further are present.

The brazing of AZ31 is still in the development stage. It is possible to braze this alloy, but the filler materials are of high alloy content and therefore somewhat brittle. This limits the brazing to joints not requiring formed filler alloys. Calcium additions of about 0.2% are made to the sheet material. The solidus is thereby reduced from 1050 F to 980 F. This means that filler alloys for AZ31 sheet should melt and flow below 980 F.

Many magnesium base filler alloys which melt below 1000 F have been investigated but most of them had undesirable characteristics such as extreme brittleness, corrosiveness, or diffusion. Of the alloys investigated, the ternary magnesium-aluminum-zinc alloys appeared to possess the best corrosion resistance and capillary flow. An investigation of the magnesium-rich corner of this system indicated that alloys up to a total alloy content of 30% had satisfactory capillary flow. However, as the aluminum and zinc contents increased the brittleness and diffusion rates also increased, until at 30% alloy content brazing was impractical. Since some measure of ductility in the filler metal was required for forming into rings, bands, or washers for preplacement, AZ92 or Dow C alloy (magnesium + 9 aluminum + 2 zinc) offered the best all-around properties. This alloy possessed the most desirable characteristics, such as ductility, corrosion resistance, capillary flow, high strength, and sufficiently low melting point, for brazing M alloy. The melting point or liquidus of C alloy is 1106 F, making it possible to braze at 1130 to 1160 F, which is safely below the solidus of M alloy. Other higher alloy content alloys with lower melting points could also be used but their ductility is much less and it becomes increasingly difficult to extrude or roll them for forming into proper shapes for preplacement.

An alloy that has excellent capillary flow at 1075 to 1100 F is AZ125 (magnesium + 12 aluminum + 5 zinc). Its melting point is approximately 1065 F.

This alloy is primarily recommended for torch brazing since it is less ductile than AZ92 and therefore cannot be readily formed into rings, bands, or washers for preplacement.

As already indicated, magnesium alloys can be heated to high temperatures without danger of burning, provided the temperature is kept below the solidus of the alloy in question. Recent work has indicated that the ignition temperature may fall below the solidus in the presence of moisture. However, it is believed that this moisture in the heating atmosphere would have very little if any effect on the ignition point in brazing since the heating times are relatively short.

In the early tests, some unpredictable burning of the brazing alloys was obtained in furnace brazing tests even at temperatures below 1000 F. A large variety of flux compositions were tried without finding any that would completely eliminate the burning and also give good capillary flow. Since beryllium was known to inhibit the burning of molten magnesium alloys, the addition of small amounts of this metal to the brazing alloys was tried. The result was a complete elimination of burning. It was established that a minimum of 0.002% beryllium was required for complete protection. The beryllium was necessary only in the furnace brazing method. Apparently, the relatively longer heating of the flux in contact with magnesium in the furnace atmosphere resulted in a loss of protection of the brazing alloy. No burning has been experienced in torch and flux dip brazing and, therefore, beryllium in the filler alloys is not necessary. The presence of beryllium in alloys has no appreciable effect on capillary flow.

Fluxes

Special chloride base fluxes consisting of KCl-NaCl-LiCl with small amounts of various fluorides are used in the brazing process. Dow 451 brazing flux is used with AZ92 filler alloy, while Dow 452 is used when brazing with AZ125. The compositions and approximate melting points of these two fluxes are given in Table III.

The majority of magnesium gas welding fluxes are mixtures of KCl-NaCl-LiCl in varying proportions. Therefore, many of the commercially used welding fluxes should be satisfactory for brazing, especially torch brazing. In furnace brazing, flux composition is more critical so only special fluxes specifically recommended for brazing should be used.

The application of the flux on the joint prior to brazing will depend on the brazing method. In furnace brazing, the best results are obtained by sprinkling the dry powdered flux around the joint. Water or alcohol pastes are unsatisfactory because the capillary flow is greatly reduced. Apparently these pastes react with the magnesium to form oxides or hydroxides which impair the wetting of the parent metal by the brazing alloy. However, the water or alcohol pastes can be used in torch brazing fairly satisfactorily, although alcoholic pastes give much better results and should be used in preference to water pastes. This difference in behavior is probably accounted for by the mechanical breaking of any film in the process of depositing the filler metal manually in torch brazing. If it is necessary to use flux pastes in furnace brazing, an inert easily volatilized liquid, such as benzene, toluene, or chlorbenzol, can be used. The application, however, is not as smooth as with water or alcohol pastes. These organic liquids are driven off by heating at 350 to 400 F for 10 to 15 min. in drying ovens or circulating air furnaces. Flame drying should not be used as heavy soot formation will result.

Preparation of Materials

As in the brazing of other metals, the parts should be thoroughly clean and free from all oil, dirt, grease, and surface films such as chromates or oxides. Either mechanical or chemical methods of cleaning can be used. In mechanical cleaning, abrading with aloxite impregnated cloth or with steel wool has proved very satisfactory. If a chromate film is present, it should be removed to within an inch or more of the joints since the capillary flow of the brazing alloy is reduced if the flux contacts the chromate film.

Chemical cleaning is accomplished by thorough degreasing in a vapor or solvent degreaser, followed by a 5- to 10-min. dip in a hot alkaline cleaner and then a 2-min. dip in the cold Dow Bright Pickle solution. The vapor degreasing step can be eliminated if the material is unoiled and reasonably clean. The hot alkaline cleaner also removes any chromate film that might be present. Indications are that almost any etching solution that does not leave a heavy film might serve as a cleaner prior to brazing. Solutions of 2% acetic acid and 5% citric acid were quite satisfactory on M alloy but left a black smudge on the aluminum and zinc containing alloys such as AZ92. After pickling, the parts are rinsed in cold and hot water and allowed to dry in air.

The brazed joints should be washed free of flux

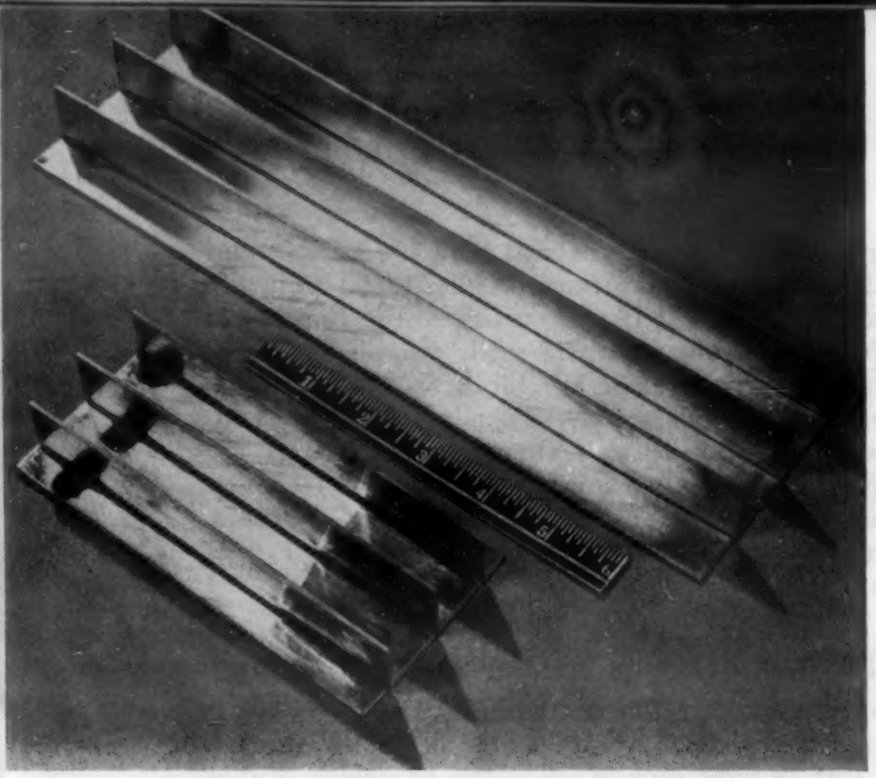
Table II—Effect of Heating Time at 1160 F on the Tensile Properties of M1 (Ma) Soft Annealed Sheet

Heating Time, Min.	Psi. Tus	Psi. Tys	% Elongation in 2 in.
5	17,500	5,700	5.0
8	16,600	5,900	5.5
15	16,600	5,900	5.5
30	16,100	5,700	5.0

Table III—Composition of Dow Brazing Fluxes

Dow Flux No.	%KCl	%NaCl	%LiCl	% Others	Approximate Melting Point F	Approximate Melting Point C
451	42	21	23	4 NaF, 10 LiF	1000	538
452	42.5	10	37	10 NaF, ½ AlF_3.3 NaF	730	380
450*	46	24	26	4 NaF	1000	538

*Gas Welding Flux



Close inspection of this illustration will show the extent of capillary flow of the brazing alloy on furnace brazed inverted T-joints.

in hot water, preferably within half an hour after brazing. The fluxes are quite hygroscopic and unless washed off, a pitting type of corrosion will result. After the flux is washed off thoroughly, the pieces should be Chrome-Pickled for 2 min. (Dow No. 1 Treatment), then boiled for 2 hr. in 5% sodium dichromate solution to leach out any residual flux from tiny crevices. This cleaning treatment is also used on gas welds.

Furnace Brazing Technique

Furnaces heated by gas or electricity with automatic temperature control should be used. No special atmosphere is required but the products of combustion in gas fired furnaces should not be allowed in the brazing chambers. Active atmospheres, such as combustion products and SO_2, the latter being used to prevent burning of magnesium alloys during heat treatment, reduce the capillary flow of the metal. The temperature should be controlled within plus or minus 5 deg. F. Circulation of furnace atmosphere is not essential but is a desirable feature since it reduces the heating time and results in more uniform heating of the parts. Local overheating by radiant heat from the heating elements should be guarded against, especially when brazing with AZ92 alloy at 1160 F, since melting and burning of the parts may result.

The brazing time depends on the thickness of the materials being brazed. Therefore, the joints should be designed so as to keep the differences in thickness of materials to a minimum. Usually, about 2 min. at brazing temperature, exclusive of the time required to reach the temperature, is sufficient for the brazing alloy to melt and flow into the joint. For example, when brazing 0.064-in. sheet material, a total time of 5 to 8 min. in the furnace is required, depending on furnace used and other conditions. In general, the best time is established by a few preliminary tests in any one furnace. The brazed joints are usually cooled in air after removal from the furnace.

Torch Brazing

Torch brazing is accomplished with the standard gas welding equipment using a neutral oxyacetylene or natural gas-air flame. The operation is much the same as in gas welding except that a lower flame temperature is used. The flame is concentrated on the base material and the rod is dipped into the puddle intermittently. When starting a joint, the rod is not added until the surface just begins to melt. If the base metal is overheated to a point of almost complete fusion, as in welding, the brazing metal will sink or drop through, leaving a hole.

The standard AZ92 alloy or other compositions without beryllium can be used in torch brazing. There is no burning since adequate protection is afforded by the flux. Manual brazing with AZ92 alloy is a critical operation and requires considerable skill. A lower melting point alloy, such as AZ125, is preferred.

Most of the ordinary magnesium gas welding fluxes are satisfactory with AZ92 alloy in manual brazing, but for the lower melting point alloys Dow 452 should be used for best flowability. An alcoholic flux paste brushed on the joints and on the rod is quite satisfactory.

The brazing of magnesium parts by fixed localized heat is quite readily accomplished. Tests with Bunsen or Selas ceramic burners using a natural gas-air mixture resulted in satisfactory joints. Best results were obtained in these tests by the use of the special fluxes, Dow 451 and 452. Electric resistance and induction heating have not been tried but it is believed they would also prove quite satisfactory.

Flux Dip Brazing

Steel, nickel, or clay-graphite crucibles are satisfactory containers for the molten flux baths. The bath is discolored when in steel pots, but the fluxing action does not appear to be affected. Heating can be by electricity or gas. Either AZ92 or AZ125 alloy can be used as filler material. Beryllium in the brazing alloys is not required, but its presence has no significant effect on the flow of metal. No special fluxes are required and many of the gas welding fluxes should be satisfactory. The time of brazing is short. For example, only 30 to 45 sec. are required to braze 0.064-in. material compared to the furnace brazing time of 5 to 8 min. Because of the rapid heating and the relatively large volume of flux, much more consistent results and much better flow of brazing metal are obtained. Also, lower temperatures than in furnace brazing are used, generally only a few degrees above the liquidus of the brazing alloy. For the AZ92 alloy, temperatures between 1120 and 1130 F are satisfactory, while for AZ125, temperatures of 1070 to 1075 F are used. The flux dip method, however, is limited to the brazing of certain types of joints because of the tendency of the filler alloy to be washed away unless special precautions are taken.

Joints and Joint Design

Brazed joints should be so designed that the flux is swept out by the brazing material as it flows into

the joint. The design should also facilitate the flow of the filler metal and permit easy assembly. The best types of joints for furnace brazing are the lap and line contact or fillet forming joints.

As in the brazing of other metals, suitable clearances between the mating parts are essential to permit capillary filling of the joints. Clearances from 0.004 to 0.010 in. are satisfactory for the type of joint where vertical tubes are brazed to sheet. In joints where flow is entirely by capillarity and against gravity, such as in tubular joints placed in a horizontal position, smaller clearances from 0.004 to 0.006 in. are best. In general, while there appears to be a fairly large range, it is best to design for the least clearance that will permit good flow of metal in order to take full advantage of capillary forces.

In flux dip brazing, the joints should have slots or recessed grooves for placement of wire rings or bands of filler metal. If these precautions are not taken, the filler metal may be washed off into the flux bath. The brazing temperature of 1160 F was a little too high and the time of immersion was a little longer than necessary.

Strengths of brazed joints were determined on test bars 1-in. wide made from 0.064-in sheet. The results of tests are given in Table IV. All failures occurred outside the joints in the sheet material. Therefore, the strength values for the different joints are those of the material from which the bars are made rather than of the joint itself. Table II shows the results of tests on heated unbrazed sheet. The strength drops to about 50% of the original value. The slightly lower values for the brazed joints in comparison with the heated sheet are due to eccentricity in the testing of lap joints. The strengths of furnace brazed joints will therefore lie between 14,000 and 16,000 psi. This compares closely with values of 15,000 psi. for 3S aluminum joints. The torch brazed butt joints average 23,000 psi., which is slightly higher than is obtained with gas welds. These results indicate that even higher strengths are obtained with brazed joints provided a higher strength base metal is used.

Specimens exposed to 95% humidity to check the effect of possible entrapped flux appeared to show slightly lower values than unexposed bars. However, since all failures occurred outside the joints, the difference was attributed to scatter. There was but a slight evidence of flux blooming and, therefore, the amount of flux entrapped had no significant effect on strengths.

Flux Inclusions

As already indicated, some flux entrapment may occur in brazed joints but the amount is so slight that even under as severe an exposure as 28 days in 95% humidity there is no visible effect on strength. Painted and unpainted brazed panels on exposure to indoor and outdoor atmospheres over a period of nine months showed only slight traces of flux. Painted panels in indoor exposure, also for nine months, have shown no evidence of paint blisters in the joints while outdoor panels have shown only one or two blisters per foot of brazed joint. There is no galvanic corrosion problem in brazed joints since the brazing alloy and

Table IV—Strengths of Magnesium Alloy Brazed Joints

Brazing Alloy	Average* Tensile Strength—Psi. Furnace Brazed Joints** 5/16-in. Lap	3/8-in. Lap	Butt	Torch Brazed Joints Butt
AZ92 (Dow C)	15,940	16,500	16,300	23,600
	After 7 days in 95% humidity			
AZ92	14,400	16,300	—	—
	After 28 days in 95% humidity			
AZ92	14,400	14,900	—	—

*Average of 6 test bars
**Brazed at 1160 F—held in furnace 6 min. Material—0.064-in. M1 sheet (Dow Ma)

the parent material are commercial magnesium base alloys.

Joint Appearance

The brazed magnesium joints have smooth meniscus type fillets which require no finishing. The fillets are somewhat larger than in other brazing metals except aluminum alloys. This is an advantage, especially for magnesium alloys, since the gradual change in contour reduces stress concentration at sharp corners or angles.

In the unpickled condition, the brazing alloy gives good color match. When given the Chrome-Pickle treatment (Dow No. 1), the brazing alloy is darker in color.

At the present time, the brazing of magnesium alloy parts is limited to assemblies made of M1 alloy. However, since the brazing process has just emerged from the laboratory to a commercial status, many new developments in both techniques and applications may be expected in the near future. The development of the magnesium alloy brazing process can only be regarded with the fullest optimism because of its possibilities for the rapid economical joining of many parts.

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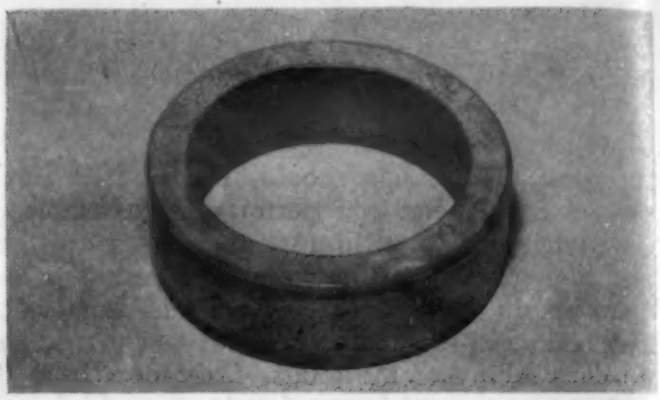
Small quantities of indium in lead provide qualities which permit bearings of this type to function under extremely difficult conditions.



Here is one type of lead-indium plated bushing used in aircraft carrier landing installations.

Indium Plated Lead Bearings Withstand High Stresses

by JOSEPH ALBIN

SOME OF THE CHARACTERISTICS of lead which make it suitable as a bearing metal are considerably improved by small additions of indium. Notably in aviation engines, the lead-indium plating of bearings has made possible longer periods between engine overhaul. The indium deposited and subsequently diffused into the underlying coat makes the bearing surface harder and tougher, as well as more resistant to the corrosion by the lubricant. In one novel application, described below, where bearing pressure went over 10,000 psi. sufficient to suspend lubrication entirely in an untreated bronze bearing, the use of lead-indium plating permitted satisfactory operation of the device.

Lead-indium plating normally goes over a silver base which in itself is supported by a steel shell. Silver has the internal properties which resist failure due to fatigue. To make up for the lack of "oiliness" needed in a good bearing surface, a thin layer of lead is electrodeposited over the silver surface. Lead, however, is soluble in organic compounds present or formed in lubricating oils with rises in temperature due to engine operation. To prevent the corrosion of the bearing surface and to permit the surface to retain its oil film more completely by increasing its wettability, a thin or practically flash coating of indium is electrodeposited and heat processed.

Hardening of the lead is accomplished by the diffusion of the indium. Addition of 4 to 6% indium markedly changes the relatively large crystalline structure of lead to that of a finely furrowed appearance. On the Brinell scale, 8% of indium increases hardness from 3.11 to 7.28. The addition of 1% increases tensile strength from 1,600 to 3,000 psi.

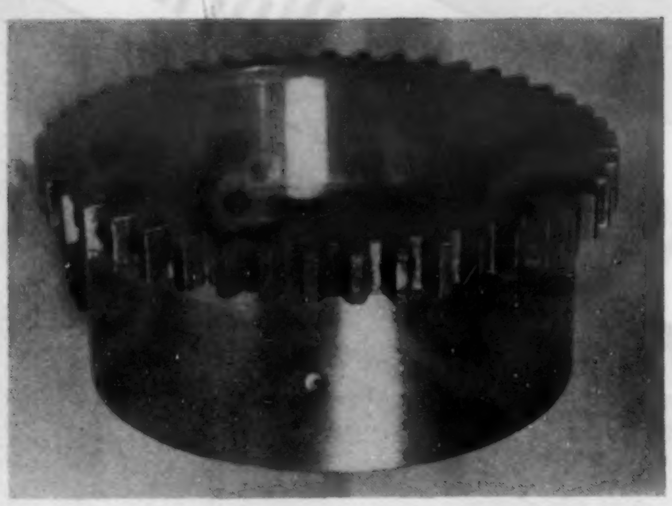
While the majority of aviation bearings are silver-lead-indium, other metals onto which indium can be plated and diffused are copper, cadmium, zinc and tin. Much experimental work and testing has been done on this series of indium bearings by aviation and automotive companies, and manufacturers of diesel and stationary engines. Lead-indium bearings have also found application in machine tools.

Whereas the lead-indium plating of bearings for airplane engines exemplifies the dual handling of corrosion and high stresses developed through continuous running of the machine, the problem of extremely high bearing pressures is featured in a Navy landing gear equipment installed on airplane carrier flight decks.

The lead-indium work for this device has been done by the Standard Machinery Co., Providence, R. I. This work involves bushings installed in large sheaves used in connection with the landing gear. The installation involves the use of blocks made up of 6 or 8 large sheaves around which is wrapped a heavy steel cable which, in turn, is attached to a hydraulic cylinder. An end of this cable is stretched across the flight deck in such a way that it engages a hook on the landing airplane. As the oil is being exhausted from the cylinder through a valve, the plane is brought to a relatively gradual stop from speeds of approximately 100 miles per hr. in a distance of 100 ft. The bearing pressure developed during this sudden braking of the airplane's motion is very high, of the order of 10,000 psi., at which pressure conventional pressure lubrication is rendered inoperative.

The frequent seizure of the sheave bearing and the scoring of the bronze surface of the bearing led the Navy to consider possibilities of a solution by lead-indium plating. The problem of doing the experimental work and development of a lead-indium bearing suitable for this particular Navy service was

Indium plated bearings operate without seizure as lubrication is suspended by high pressures.



Aircraft master rod bearings are reprocessed with lead-indium bearings by American Airlines. The gear is mashed to keep it from being plated.

handed over to the Standard Machinery Co.

Best results were obtained through the use of silver-lead-indium coatings applied electrolytically in sequence and alloyed by heating. Bronze bearings treated in this fashion provided a superior service, and the company has manufactured hundreds of these bearings for the Navy.

In connection with the investigation, the company built a special machine, hydraulically operated, which simulated the service to which the bushings are subjected in actual service. With this machine, engineers were able to run up thousands of pressure cycles equivalent to those developed during a plane's landing.

Types of Baths

The controls and specifications of lead-indium plating are very rigid. As is true with all general plating, freedom of the base metal from dirt, grease and oxide film is essential. At American Airlines' main overhaul base, Tulsa, Okla., where lead-indium plating of the master rod bearing for the Pratt & Whitney engine is done, a deposition test of the indium bath is made each day of use. An analysis is carried out weekly. American Airlines reprocesses this bearing under a licensing arrangement with Pratt & Whitney Co., which owns the patent for this airplane bearing. Indium, in concentrated solution form or metal, is supplied by the Indium Corp. of America, Utica, N. Y., which has done much research in indium plating procedures.

There are four types of baths for indium plating which have been used commercially with varying degrees of success. These can be divided into the solution bath and the bath requiring indium anodes for replenishment.

The solution bath is a clear indium cyanide plating bath which is free from sludge and of high alkalinity. It is available in concentrated form and it is only necessary to dilute the concentrate with an equal amount of water in preparation of the bath. This procedure can be followed in the replenishment of the bath as it is expended.

The current density for the cyanide bath is 15 to 20 amp. per sq. ft. For the anodes, plain steel is preferred to stainless steel, carbon or platinum. The latter anodes tend to catalyze the oxidation of organic matter, which increases the possibility of sludging. The bath is kept at room temperature, with or without agitation. The cathode efficiency is about 75%. Throwing power—excellent. Control of the solution is by analysis for cyanide and metal.

The baths requiring an indium anode for replenishment are as follows:

(a) *Sulfate bath*—contains about 2½ oz. of indium in solution per gal. The sodium sulfate content is about 3¼ oz. per gal. The pH of the solution is between 2.0 and 2.5. Current—20 asf.

(b) *Fluoborate bath*—Concentrated solutions of indium fluoborate are diluted with proper proportions of water. The bath is stable as long as a slight excess of fluoboric acid is present. The pH of the bath is approximately 0. and 0.2. Operation temperature—between 75 and 90 F. A current density of 100 asf. is employed.

(c) *Sulfamate bath*—Operates satisfactorily with 2½ oz. of indium metal per gal. The current density is as high as any bath and is not critical. The indium content is supplied by indium anodes, and the efficiency of the bath is maintained by control of the pH and the indium content.

After the plating of indium, the second phase in order to secure the full values of the deposit, is to have the indium diffused into the base metal. This is done by placing the plated part in an oven or hot bath and subjecting it to 2 hr. of heat treatment at a point slightly above the melting point of indium. As indium melts at 311 F, the diffusion should be carried out at about 350 F. This process may be shortened by increasing the temperature, but only after the diffusion has actually begun. Failing to observe the proper temperature at the beginning of the diffusion process may lead to the formation of surface bubbles.

The amount of indium used is extremely small, and in most cases does not exceed 5 milligrams per sq. in. The thickness of the undercoating will vary from a few ten-thousands to one or two thousands of an inch. The thickness of indium deposit depends on surface requirements.

Materials at Work

IMPREGNATED FABRIC CUTOFF WHEEL *A new type of abrasive cutoff wheel which is flexible, thus shatterproof, is being introduced for use in cleaning and snagging operations on both ferrous and nonferrous casting. The wheel, developed by Norton Co., Worcester, Mass., consists of several thicknesses of strong fabric impregnated with a resinoid-bonded abrasive. In a test, a steel rod was thrown against a revolving wheel with such force that a hole was torn in the wheel without causing it to shatter.*

— A special feature devoted to showing how materials are used as well as why they are used in their newer applications. Here you will find interesting, informative items and illustrations showing the methods by which progressive engineers are taking advantage of the properties of materials—both new and old.

PLASTIC LENS *In G.E.'s new photoelectric light meter, a polystyrene lens is used to pass light to the surface of the photocell. The plastic lens is said to increase the photometric efficiency of the meter. The lens is designed in cylindrical form with only a slight curvature of the axis and improves light distribution and thereby the response to light flux. Polystyrene is only one of four different plastics used in the meter. Others include: a methyl methacrylate scale plate window; phenolic case; and a cloth-based laminated plastic regulator.*

CUNICO MAGNETS REPLACE JEWEL BEARINGS

An interesting new application of permanent magnets is revealed by General Electric in announcing its new watthour meter. A small amount of magnetic material supports all the weight of the meter's disk and shaft. Two cylindrical permanent magnets made of cunico are placed one within the other. The outer magnet is fixed to the meter frame and the inner magnet is attached to the upper end of the disk shaft. The concentric magnets are magnetized axially with opposite polarities. The resulting field supports the rotating parts at a definite, small downward displacement. Among other advantages expected from this application is the elimination of bearing maintenance. Cunico, the permanent magnet material is easily machined.

ALUMINUM PIPE LINE *A two-mile stretch of pipe line at Magnolia, Ark., utilizes 63ST6 aluminum alloy pipe to combat corrosive conditions which destroyed steel piping formerly used. The line carries "sour" oil. Corrosion engineers believe the "sour" oil contains hydrogen sulfide which combines with water to form a highly corrosive acid which eats out steel pipe in about one year. In this instance 40-ft. lengths of 6-in. dia. pipe (wall thickness 0.280 in.) were welded by the inert-gas method. The high frequency a.c. current needed for this type of welding was provided by a gasoline driven Hobart welder.*

Materials at Work

ABRASION RESISTANT RUBBER

Armorite, an abrasion resistant rubber compound, is proving itself as the wall lining of shot blast rooms. Formerly, in one instance, 2-in. thick wooden planks were used as lining. Abrasive action of the steel shot used for blasting was so destructive that the walls were destroyed after about one month. B. F. Goodrich Co., Akron, Ohio, producers of Armorite, report that the illustrated installation has been in service for more than a year without showing appreciable wear.

MUSIC FROM SUPERTENSILE STEEL WIRE

A new steel wire, said to be the strongest wire of its size known today, has a tensile strength of approximately 460,000 psi. One of the first uses of the wire is as an "A" string to give tenor banjos and guitars a range 3½ tones above their normal. For instrument use the steel wire is gold plated. The high quality wire is produced by a special combination of heat treatments and exceptionally long cold working. The wire is 0.010 gage, permitting vibrational loads up to 37.7 lb. Made from high carbon steel, the wire was developed at the Worcester, Mass., works of American Steel & Wire Co.

PLASTIC AUTO TOPS

Anticipating the day when automobiles will be equipped with plastic tops, The Curran Corp., Lawrence, Mass., is supplying its road salesmen with cars so equipped. In addition to their practical value, plastic tops have high novelty value. The plastic used is a new methacrylate similar to that used in some types of military aircraft.

ATERIALS & METHODS MANUAL

This is another in a series of Manuals on engineering materials and their processing published as special sections in Materials & Methods. Each manual is complete in itself and is intended to serve as a reference book on the subject covered. These manuals provide the reader with useful data on characteristics of materials or fabricated parts, and on their processing and application. Preceding manuals have taken their places in the permanent reference files of thousands of readers.

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Electroplated Coatings

by George Black

Development of the science of electroplating has now reached the state where very specific characteristics can be provided in coatings to make them suited for definite applications. To achieve the results that are possible with electroplating requires a wide variety of plating materials, several types of plating baths, and a range of processing equipment. It is the purpose of this manual to present all elements entering into the selection and application of electroplated coatings in such a way as to make possible their most intelligent use.

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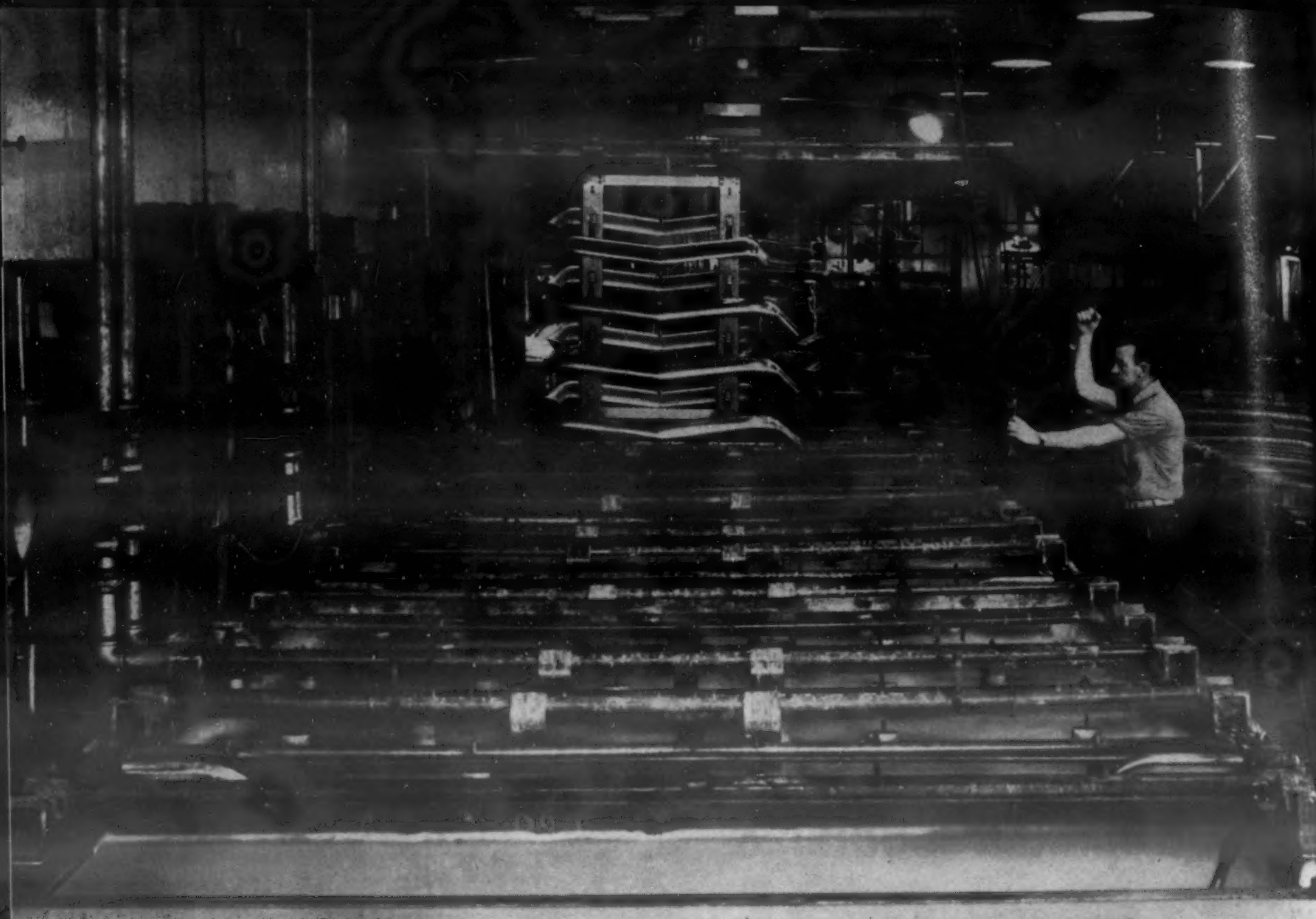


The automotive industry is probably the largest user of electroplated parts. Here in the plant of Gerity-Adrian Mfg. Co. a rack of automobile grille bars is emerging from one of a series of plating tanks. (Courtesy: United Chromium, Inc.)

Introduction

Electroplating, which has been defined as the deposition of an adherent metallic coating upon an electrode, covers such a wide variety of metals, solutions, equipment, current requirements, application procedures and methods of control that an intelligent choice of a specific coating is indeed difficult. It is the purpose of this manual to present the data basic to an understanding of what is commercially available, and to offer sufficient information about each of the current methods and applied coatings so that the values and shortcomings of various electroplates may be better understood.

Purposes

Although it is generally agreed that electroplated coatings are used either for protection or for decoration, these terms are much too general and barely begin to explain the wide variety of metals, solutions, methods and controls. The following list offers a picture of the importance of electrodeposition to the industrial and commercial worlds:

1. *Decoration* — Electroplated coatings are used to alter the color, texture or general appearance of the base.
2. *Protection from atmospheric corrosion*—By plating a base metal with one which is more corrosion resistant, protection from rusting can be achieved.
3. *Protection from galvanic corrosion*—Years of extensive research, studying the behavior of the various metals in contact with each other, have established the "galvanic series," which is an arrangement of the various metals in tabular form so that the corroding or protecting effect of any one metal on any other metal in the series can readily be determined. By coating the base metal with a metal closer in potential to the adjoining metal, the destructive effect of dissimilar contacts can be avoided or lessened.
4. *Changing the electrical or thermal conductance value* — By plating a base metal of high resistance with a metal of low electrical resistance; or through metallic plating on a non-conducting surface such as wood, plastic or rubber, the conductance value can be appreciably altered to suit the occasion. In the same manner the thermal conductance value of a given surface can be altered to meet specific needs.
5. *Protection from the action of a specific chemical*—Knowing the chemical resistance properties of the various metals, it is possible to choose a coating which will protect our base metal from exposure to a given

corrosive agent or from other effects of chemical combination.

6. *Changing reflectance value*—The wise choice of metals with high reflectance or those offering nonreflecting surfaces enables the use of a wide variety of base metals and the ultimate attaining of the same reflectance value.
7. *Repair of worn tools*—Choosing metals with the characteristic hardness as electroplates on surfaces which have worn below tolerance, has led to the salvaging of thousands of dollars worth of used tools and equipment.
8. *Altering resistance to impact and abrasion*—It is entirely possible, by the proper selection of an electroplate, to appreciably change the physical values of the surface. The plating of hard coatings on relatively soft metals or on certain non-conductors increases the wear and abrasion resistance of the part.
9. *Varying the coefficient of friction*—By the wise selection of materials with low coefficients of friction, bearing or sliding surfaces are supplied in specific areas on surfaces which would ordinarily bind.
10. *Electroforming*—This is a completely separate field of electrodeposition which is defined as the production or reproduction of articles by electrodeposition. It includes electrotyping, the reproduction of phonograph matrices and the manufacture of tubes, sheets and a wide variety of close tolerance parts.
11. *Electrowinning and electrorefining*—These are two related processes for the recovery and purification of metals which use the science of electrodeposition as their basis.

This is but a partial list. During the past few years electroplating has shown an almost unparalleled growth. Laboratory curiosities of yesterday, such as plating on plastics, continuous high-speed deposition, accurate thickness control, and the like, are standbys today. Recent developments indicate clearly that the future of this $300,000,000 industry offers an optimistic picture to a wide variety of manufacturers.

In order to understand that picture, however, it is essential that we know the basic characteristics of the metals to be used; that we understand the advantages and shortcomings of the various types of solutions; that we know what is available in the way of related equipment; and that we fully comprehend the terminology we will run across in the trade literature. The choice of the best electroplate for a specific purpose is not a matter of good luck—it is based on a full knowledge of the factors enumerated, plus an understanding of demand, cost and availability.

Alloy Deposition

The metalworking industries have long known the benefits of using two or more metals in chemical combination, and it is only natural for the electroplater to seek the same advantages. The use of indium coatings which are fused to predeposited metal, and the whole series of nickel-tin and nickel-zinc coatings are good examples of the electrodepositor's attempt to achieve the benefits of alloying practices.

The electroplating of two or more metals individually, with subsequent heat treatment to secure the alloy properties, represents additional expenses, tied up with equipment, time and labor. The more economical method is to deposit the alloy directly from a single bath, and a great deal of progress has been made during the last few years in the control of the solutions used, and the composition of the alloy being deposited.

The alloy deposited most widely is brass. It provides a coating which is both decorative and protective, and has been used extensively as a base to secure adhesion of rubber coatings. Bronze plating is done on a limited scale. When the bronze color is required, it is usual practice to juggle the constituents of a brass plating bath so that a bronze color is obtained.

Lead-tin alloys have been deposited to provide a good bearing metal, but the standard practice is to deposit the metals individually and then fuse them in an oil bath at temperatures of 350 F. The deposition of lead-silver alloys results in a good bearing surface, and excellent long-time results have been obtained from easy-to-operate cyanide baths.

The whiteness of zinc coatings has been materially increased through the deposition of a zinc-cadmium alloy, and cadmium-silver alloy deposits are known to have less tendency to tarnishing than silver alone. There are still many problems to be worked out before cadmium-silver electroplating will be commercially advisable, but the added permanence given to the silver by the combination has led to wide research.

The whole field of alloy deposition is worth watching with interest, as electrochemists are determined to reap the benefits of the metal industries in their use of chemical combinations of various metals. Listed below are five important reasons why alloy plating is the subject of so much study at the present date:

(1) Reduction of metal cost (*e.g.* nickel-iron instead of nickel).

(2) Special and variable color effects for decorative purposes (*e.g.* brass and gold alloys.

(3) Production of bright deposits (*e.g.* nickel-cobalt and zinc-cadmium).

(4) Possibility of the deposition of rare metals in useful alloy forms, especially when such metals are not capable of satisfactory deposition alone.

(5) Special properties (*e.g.* brass for rubber adhesion and silver-cadmium for resisting tarnish).

Definitions Basic to an Understanding of the Literature of Electroplating

Addition Agents—Compounds that are dissolved in electroplating baths for the purpose of improving the deposit.

Anode—The positive pole of an electrolytic cell.

Anode Corrosion—The electrochemical reaction with soluble anodes that causes their solution in the bath.

Buffer Action—The action of a weak acid, such as boric acid, in maintaining nearly constant hydrogen ion concentration.

Cathode—The negative pole of an electrolytic cell.

Cathode Efficiency—The ratio of actual metal deposited on the cathode to that which is theoretically deposited based upon the amount of current flowing.

Conductance—The ability of a material to carry or conduct electric current.

Coulomb—The unit quantity of electricity. One coulomb per sec. equals one amp.

Current Density—The current flowing in a unit area, such as amp. per sq. ft.

Double Salt—A salt containing two metal elements.

Drag Out—The losses of electrolyte by adherence to the cathodes when the cathodes are removed from the electroplating tank.

Electrochemical Equivalent—The mass liberated by the passage of a unit quantity of electricity.

Electrolysis—The action of a direct current in passing through a solution of an acid, base or salt, in which the acid, base or salt is separated into its elements.

Faraday—The unit of electrochemical reactions, equal to 96,550 coulombs. One faraday deposits the gram equivalent weight of a metal.

Hydrogen Ion Concentration (pH)—The concentration of hydrogen ions in the solution as expressed numerically.

Passivity—The inability of a soluble anode to dissolve in the plating solution by electrolytic corrosion; frequently caused by the formation of an oxide film or other compound on the anode surface.

Strike—A thin electrodeposit of metal obtained by a short period of immersion in a solution lean in that metal.

Throwing Power—The difference between actual metal distribution and primary current distribution, expressed as a per cent of primary current distribution. Good throwing power means the ability to deposit successfully in crevices and on far corners.

Valence—The number of atoms of hydrogen with which a chemical element or radical will combine or displace.

Characteristics of Electrodeposits

Coating Metal	Characteristics	Uses
Cadmium	Attractive, relatively soft, relatively high-priced corrosion resistant coating. It dissolves slowly in alkalies, and protects iron and steel through sacrificial action. Surface must be treated with chromic acid or specially prepared after-treatments in order to secure adequate paint adhesion.	Because of its relatively high price, cadmium is usually used indoors or in protected areas where thin coatings will suffice; however, aircraft, marine and military outdoor uses are common because of the high degree of corrosion resistance offered. Since it dissolves slowly in alkalies, cadmium is widely used to protect washing equipment, factory partition legs, steel imbedded in concrete, and similar parts. Being closer in potential to the aluminum alloys, cadmium is used for steel parts which mate with the less noble metals to lessen the effect of the galvanic attack. The electrical industry has made wide use of cadmium because it is easily soldered and has good conductivity.
Chromium	Highly decorative, extremely hard and wear resistant coating. Low coefficient of friction, excellent reflectivity and remarkable resistance to atmospheric corrosion. Accelerates the corrosion of exposed iron or steel, and is therefore applied in heavy deposits, or in thin deposits over other electroplates such as copper and nickel. The typical "chrome" plate used on household items and on automobiles consists of a thin copper plate, a relatively heavy nickel coating (the heavier the nickel, the greater the corrosion resistance), and an extremely thin flash of chromium.	Primary use of chromium plating is the thin flash applied to consumer items such as automobiles, vacuum cleaners, typewriter parts, waffle irons, etc., where its high luster and tarnish resistance offer an attractive, salable finish. The other wide use is generally referred to as "hard" chromium plating, and consists of the deposition of heavy coats to take advantage of its special characteristics—resistance to heat, low coefficient of friction, high impact and abrasion resistance, and resistance to corrosion. It has been widely used for the building up of worn surfaces, the creation of bearing surfaces, and for the facing of a large assortment of parts requiring resistance to erosion, corrosion, or wear.
Cobalt	Expensive, highly reflective, hard, corrosion resistant coating. Similar to nickel coatings, but much more expensive; thus cobalt is rarely used by itself. The high cost with respect to nickel, to which cobalt is so similar, has dimmed interest somewhat, except insofar as cobalt is used in alloy plating to add specific properties to other metals.	Used commercially on printing plates because of its hardness, and on mirrors and reflectors because of its high reflecting power and its resistance to oxidation. Codeposited with nickel to increase corrosion resistance of nickel deposits, and widely used as a codeposit in "bright" nickel plating.
Copper	Highly corrosion resistant coating with high electrical conductivity, heat conductivity and ductility. Attractive as a final finish, and entirely suitable for subsequent electroplates.	Universally used as an undercoating for nickel and chromium to make up the popular "chrome" plate. Widely employed for electric lines, window screening, and architectural sheet metal work. Used extensively in electroforming for the making of electrotypes, records, dies, etc.
Gold	Relatively scarce, high priced, decorative coating with high resistance to tarnish, oxidation and to all forms of corrosion. The most malleable of all metals and a good conductor of electricity with high thermal reflectivity.	Used for ornamental and decorative work, where its presence lends beauty, tarnish resistance and value. Laboratory apparatus is often gold plated for protection against fumes and chemical attack. Used for electrical contacts where high temperature, oxidation and low contact resistance are needed.
Indium	Relatively soft, white, tarnish resistant coating with a low melting point. Malleable and ductile. Imparts greater hardness, increased tensile strength, as well as resistance to wear, friction and corrosion when alloyed with other metals.	Most widely used as a thin plate over a previous coating of lead, cadmium, zinc, tin, gold, silver or copper; it is then diffused into the surface by a special heat treatment. Used in dental alloys, in the manufacture of silverware, and for a growing list of decorative consumer items.
Iron	Extremely cheap, hard coating with poor resistance to atmospheric corrosion.	Limited commercial application because of poor surface properties. Used for the building up of worn dimensions, but not with the same success as nickel and chromium. Interest remains keen because iron is so cheap, and at the present time, extensive investigation is going on in the field of electroforming.
Lead	Highly malleable and ductile coating with excellent resistance to acid fumes and corrosive liquids. Coating is soft, and serves as a poor conductor of electricity. It is cathodic to iron and steel, and must be used in thick deposits to prevent galvanic corrosion with subsequent deterioration of the base. Relatively cheap and easy to apply.	Little commercial use of electroplated lead coatings because they are so easily applied by the hot dip method. Used chiefly where resistance to the action of sulfuric acid is required. Lead coatings offer no decorative quality, and are too soft to provide any mechanical protection.
Nickel	Highly decorative, corrosion resistant, hard, and abrasion resistant coating. Cathodic to steel and is therefore used over copper electroplate to prevent rusting of the steel through the pores in the deposit. Excellent chemical resistance.	Widest use in the field of decorative coatings where the nickel deposit is sandwiched between thin layers of copper and chromium. It is the nickel coating which supplies the corrosion resistance, and the present tendency is toward heavier coatings so as to achieve a higher standard of quality. In the industrial field, nickel plate is used in still heavier coatings for the building up of worn surfaces or mismachined parts, for the protection of surfaces from specific chemicals, and for increasing the life of all sorts of processing equipment. Nickel plate is also widely used in electroforming
Palladium	Relatively expensive, tarnish and corrosion resistant coating. Palladium is the lightest metal of the platinum group, its reflectivity is somewhat lower than platinum, and its hardness is about the same.	Use of palladium as an electrodeposited coating is just beginning. It couples high decorative value with good tarnish resistance, and can be deposited at high speeds in coatings of any thickness. Excellent for electrical contacts, and also for electroforming applications.
Platinum	Relatively expensive, tarnish and corrosion resistant coating; the most abundant of the platinum metals. Reflectivity is higher than palladium, but lower than rhodium.	Used chiefly for ornamental purposes, and for expensive decorative articles. Recently used to plate molybdenum wire for radio tubes.
Rhodium	Highest in price of the platinum metals, but most widely plated because of its hardness, brilliant blue-white color and the simplicity of the plating operation. High reflectivity as well as tarnish and corrosion resistance. Excellent for electrical contact work in communication systems.	Extensively used as a finishing plate in the jewelry field and for reflectors for motion picture projectors, aircraft search-lights and similar applications. Mirrors or reflectors with high reflectivity and chemical stability are also made by depositing rhodium on glass.
Silver	Lustrous, soft, malleable and ductile decorative coating. The best conductor of heat and electricity known. Excellent chemical resistance. Silver undergoes no changes in water or air, but tarnishes in the vapors of sulphur compounds, forming a black sulfide.	Used widely as a decorative coating for the more expensive items, and chiefly for tableware. Used for musical instruments, surgical instruments, engineering equipment and electrical contact parts. Also widely used where its superior reflective qualities give it an advantage.
Tin	Highly corrosion resistant and tarnish resistant coating which is ductile and easily soldered. Excellent resistance to foodstuffs. Cathodic to iron and steel and therefore requires pore-free coatings to prevent accelerated attack of base.	Most common metal for parts in contact with foodstuffs. Used as a covering for copper and steel in cooking kettles, refrigerator coils, food containers and for a wide variety of relatively cheap decorative coatings.
Zinc	Relatively cheap, corrosion resistant, soft coating which protects steel and iron through sacrificial action. Only cadmium approaches zinc in the efficiency of protection afforded steel, and the price of cadmium is decidedly higher. Weathers to a dull gray and is therefore used more for protection than decoration. Newly developed clear dips which protect the bright zinc have enlarged possibilities. In order to be painted, zinc coatings must be etched or passivated in the same manner as cadmium coatings, and, generally speaking, the same after treatments work on both metals.	Used for steel wire and strip, steel screens, hardware and a wide variety of units where excellent resistance to atmospheric corrosion is more important than appearance. During the war it replaced the more critical cadmium for a large number of aircraft uses and was so well liked that when restrictions were over many firms continued plating with zinc.

The various name plates shown here show the decorative effect obtained by combining nickel and chromium plate with vitreous enamels and lacquers. These pieces were produced by the Fox Co., Cincinnati.

Properties of Coating

No matter what the field, a good job cannot be done consistently without an understanding of the materials which must be used. In electroplating, the characteristics of the metal coating being plated is the primary reason for its choice, and as such, materials data are basic in the wise selection of a coating.

The accompanying tables have been arranged so as to present this data in as convenient a form as possible.

The electrical resistivity of a metal is an important consideration in the choice of the coating. Silver and copper offer the least resistance and are therefore ideal for contact areas. During recent years shortages of these metals emphasized the necessity for understanding the conductivity of metals available as substitutes. Table II shows the metals arranged in order of their ability to conduct electrical currents, with those offering the least resistance placed at the top.

The thermal conductivity of a material is the rate of heat transfer by conduction across unit area through unit thickness for unit difference of temperature. It is measured by the number of (gram) calories conducted per second per square centimeter through a thickness of one centimeter for a temperature difference of 1 deg. C. For most pure metals thermal conductivity decreases with increase in temperature, while alloys show an opposite effect. Proper application of appropriately chosen metals can appreciably alter the thermal conductance value of the surface. Table III, below, lists the metals in order of their conductivity, with silver, the best conductor, placed at the top.

Frequent reference is made to protection of a base metal through sacrificial action of the coating, or accelerated corrosion because of higher nobility of the base metal. Perhaps a more detailed explanation of just what this means will be helpful. The simplest known form of an electric cell consists of two metals connected with each other and immersed in a conductive solution. The results of such a couple are well known—one metal is shielded while the other is attacked rapidly. Whenever two metals are in contact with each other in the presence of moisture, a similar situation is created.

The rate of corrosion varies with different combinations of metals, and experimentation has made it possible to list the various metals in order of their susceptibility to this type of corrosion. The metal which sacrifices itself is known as the anode or positive member, while the protected metal is referred to as the cathode or negative member. By choosing metals which fall in the same group the tendency toward this two-metal galvanic action is greatly reduced. A quick glance at the table should make it evident why cadmium and zinc, which are so close to aluminum in potential, are so widely used in aircraft, where the steel members almost invariably contact aluminum alloys.

Table I—Relative Weight of Electroplated Metals

Metal	Specific Gravity
1. Platinum	21.37
2. Gold	19.3
3. Rhodium	12.5
4. Palladium	12.16
5. Lead	11.35
6. Silver	10.50
7. Copper	8.93
8. Cobalt	8.9
9. Nickel	8.9
10. Cadmium	8.65
11. Iron	7.85
12. Indium	7.28
13. Zinc	7.14
14. Chromium	7.1
15. Tin	5.75

Although the weight of the metal means little by itself, in terms of specific thicknesses it can become an important factor.

Table II — Electrical Resistivity of Plated Coatings

Metal	Resistivity (Microhm-Centimeters)
1. Silver	1.63 @ 18 C
2. Copper	1.72 @ 20 C
3. Gold	2.44 @ 20 C
4. Chromium	2.6 @ 0 C
5. Rhodium	5.11 @ 0 C
6. Zinc	5.75 @ 0 C
7. Cadmium	7.54 @ 18 C
8. Nickel	7.8 @ 20 C
9. Indium	8.37 @ 0 C
10. Cobalt	9.7 @ 20 C
11. Iron	9.8 @ 20 C
12. Platinum	9.83 @ 0 C
13. Palladium	11.0 @ 20 C
14. Tin	11.5 @ 20 C
15. Lead	22.0 @ 20 C

Table III—Thermal Conductance Values

Silver	0.974
Copper	0.023
Gold	0.707
Chromium	0.65
Zinc	0.268
Cadmium	0.217
Nickel	0.21
Rhodium	0.210
Iron	0.19
Platinum	0.166
Cobalt	0.165
Palladium	0.161
Tin	0.157
Lead	0.083
Indium	0.057

Cgs. system; cal./sq.cm./cm./deg.C/sec.

Table IV — The Galvanic Series

Corroded end (anodic):
(least noble)

- Magnesium and magnesium alloys
- Zinc
- Aluminum and non-copper bearing alloys
- Cadmium
- Aluminum alloys (copper bearing)
- Mild steel
- Wrought iron
- Cast iron
- Ni-Resist
- 13% chromium stainless steel, type 410 (active)
- 50-50 lead-tin solder
- 18:8 stainless steel, type 304 (active)
- 18:8:3 stainless steel, type 316 (active)
- Lead
- Tin
- Muntz Metal
- Manganese bronze
- Naval brass
- Nickel (active)
- Inconel (active)
- Yellow brass
- Admiralty brass
- Aluminum bronze
- Red brass
- Copper
- Silicon bronze
- Ambrac
- 70-30 copper nickel
- Comp. G-bronze
- Comp. M-bronze
- Nickel (passive)
- Inconel (passive)
- Monel
- 18:8 stainless steel (passive)
- 18:8:3 stainless steel (passive)

Protected end (cathodic)
(most noble)

Table V—Solubility of Various Electroplates

Plating	Characteristics
Cadmium	Soluble in acids; ammonium nitrate; hot sulfuric acid
Chromium	Soluble in hydrochloric acid; dilute sulfuric acid; insoluble nitric acid
Cobalt	Soluble in acids
Copper	Soluble in nitric acid; hot sulfuric acid; very slightly soluble in hydrochloric acid and ammonium hydroxide
Gold	Soluble in potassium cyanide; aqua regia; hot selenic acid. Insoluble in acids
Indium	Soluble in acids; insoluble in alcohols, alkalies, ethers
Lead	Soluble in nitric acid, hot concentrated sulfuric acid
Nickel	Soluble in dilute nitric acid; slightly soluble in hydrochloric acid and sulfuric acid; insoluble in ammonia
Palladium	Soluble in aqua regia; hot nitric-sulfuric acid; slightly soluble in hydrochloric acid
Platinum	Soluble in aqua regia, fused alkali
Rhodium	Soluble in sulfuric-hydrochloric acid; hot concentrated sulfuric acid; slightly soluble in acids, aqua regia
Silver	Soluble in nitric acid; hot sulfuric acid; potassium cyanide; insoluble in alkalies
Tin	Decomposes in hydrochloric acid, sulfuric, dilute nitric acids, aqua regia, hot potassium hydroxide, sodium hydroxide
Zinc	Soluble in acids, alkalies, acetic acid

The rate of corrosion is accelerated as the distance apart in the table is increased. Any metal in the series will protect any metal beneath it, and will tend to accelerate the corrosion of any metal above it. Relative position within each group may vary with the corrosive condition, but it is fairly certain that the sacrificial-protection effect between groups can be fully relied upon to act as indicated.

Listed briefly with this manual are the physical characteristics of the various metals used for electroplating. These properties are highly important in deciding which coating to use, especially when we are concerned with decorative or abrasion resistant deposits. On the other hand, however, electroplated coatings are often used to supply specific resistance to corrosives, and in order to choose wisely it is mandatory that we know the chemical resistance properties of these metals. An accompanying table lists conveniently the solubility of the different electroplated metals in a variety of alcohols, acids, alkalies, etc.

One of the purposes advanced for electroplating was the altering of the surface hardness, and most people are familiar with the use of nickel, iron and chromium for the building up of worn surfaces and the preparation of wear resistant surfaces. Table VI below gives the hardness values which have been obtained for the various metals.

Table VI — Brinell Hardness of Electroplates

Chromium	400-950
Platinum	606-642
Rhodium	594-641
Palladium	190-435
Nickel	125-550
Iron	140-350
Copper	40-130
Silver	60-79
Cadmium	12-22
Zinc	40-50
Tin	8-9

It should be borne in mind that the electroplating of metals in the low Brinell range can be just as important industrially as plating for maximum hardness. For example, there has been wide use recently of preplated nickel sheets. The nickel deposit is controlled so that the plate is sufficiently ductile to allow forming and bending without damage. The use of tin plated strip and wire is perhaps the best example of the value of soft ductile coatings.

The decision as to the choice of the metal to be plated depends, as has been indicated, on the physical and chemical characteristics required. Once these are determined, the cost factor between expensive and cheap metals plays an important part. The literature has paid too much attention to cost, however, since the per-pound rating means absolutely nothing by itself. Cost has to be measured in terms of thickness required, throwing power of the solution from which the metal can be deposited, time required for deposition, precleaning and surface preparation methods demanded.

No attempt therefore will be made in this discussion to delve into cost factors, since they are dependent upon such a wide variety of variables that the figures to be advanced would have too limited an application. For example, expensive rhodium is now being widely used as a final coating for inexpensive jewelry. It can be applied with excellent results in such thin deposits that the cost factor becomes negligible, even when compared to the cheapest of coatings.

Types and Characteristics of Electrolytes

At the start of this manual electroplating was defined as the deposition of an adherent metallic coating upon an electrode. The term electrode implies the passage of current, which, in turn, implies a path for that passage. One of the major considerations in the whole field of electrodeposition hinges on the type of path utilized to bring the metal in contact with the areas to be plated.

The electrochemistry of the operation will be explained in a later section; it will suffice here to point out that successful deposition has been made from a wide variety of solutions—acid, neutral, alkaline—and that each type offers specific advantages which must be considered.

It would be impossible to list all the solution variations that have been suggested for successful deposition. Table VII, however, gives the basic data covering typical electroplating solutions.

Table VII—Typical Electroplating Solutions

Coating	General Composition of Solution	Remarks
Cadmium	(1) Cadmium oxide, sodium cyanide addition agents	Room temperature cyanide baths using cadmium anodes and organic or inorganic addition agents are used universally for the production of bright and semi-bright deposits.
	(2) Acid chloride or acid sulfate	Acid sulfate baths have been used commercially for electrowinning and to some extent for plating in the USSR. Acid cadmium solutions yield a coarsely crystalline deposit and are of limited value.
Chromium	Chromic acid plus catalyst acid radical	Insoluble lead and lead alloy anodes are used in chromic acid baths, with the temperature of the solution maintained between 105 and 130 F. Throwing power is poor, so anodes must be built and designed for individual jobs. Current efficiency is low, but the use of high current densities permits a fairly high rate of deposition.
Cobalt	(1) Cobalt-sulfate, sodium chloride, boric acid (2) Double cobalt salts	Room temperature solutions with cobalt anodes are most widely used. Extremely high current densities can be used, but cobalt prices still outweigh the value of the metal as a coating. Used as an alloying element in nickel baths to secure bright deposits.
	(3) Cobalt-sulfate, sodium fluoride	Investigators have found that whiter deposits could be produced from fluoride baths; however, difficulties with pitting have been encountered.
Copper	(1) Copper sulfate, sulfuric acid	Using copper anodes, the acid sulfate bath is operated over a temperature range from 75 to 120 F. It is widely used in electroplating, electroforming and electrorefining operations. Advantages include simplicity of operation and control, high cathode efficiency, and high current densities. Disadvantages include dullness of coating, and the inability to use directly on metals above it in the electromotive series, such as iron, steel or zinc. These metals must first be flashed with alkaline copper.
	(2) Copper cyanide, sodium cyanide, sodium carbonate, sodium thiosulfate	High efficiency cyanide copper process makes possible rapid application of smooth, bright, heavy deposits. Close control is required to insure bright coatings and to prevent pitting.
	(3) Copper cyanide, sodium cyanide, Rochelle salt, sodium carbonate	Rochelle-cyanide baths are operated at elevated temperatures yielding bright and fine-grained deposits. Solution control is difficult and requires extreme care, and cathode current densities are relatively low.
	(4) Copper fluoborate, metallic copper	High-speed application of thick deposits are obtained from fluoborate baths at approximately 100% efficiencies. Iron and steel require a preliminary coating from a cyanide solution.
Gold	(1) Potassium gold, cyanide, potassium carbonate, potassium cyanide	Gold cyanide baths are operated at elevated temperatures, using stainless steel anodes. Alkali phosphates are added to produce deposits of lower karat shades. Used for thin coatings.
	(2) Auric chloride, hydrochloric acid	When heavy deposits are required, a thin coating is usually applied from a cyanide bath, after which a gold chloride solution is used.
Indium	(1) Indium chloride, potassium cyanide, potassium hydroxide, dextrose	The indium cyanide bath provides an excellent coating with simplicity of controls. Indium and platinum anodes are used for room temperature application, and the indium is supplied through chloride.
	(2) Indium fluoborate, boric acid, ammonium fluoborate	Indium fluoborate baths are still in experimental stage. Good throwing power has been obtained from room temperature solutions. Close grained deposits have been obtained at good current efficiencies.
Iron	(1) Ferrous ammonium, sulfate	Using anodes of high purity iron, hard, adherent and machinable deposits are obtained from baths operating at temperatures of 140 F.
	(2) Ferrous chloride, calcium chloride	Soft deposits obtained at high temperatures (185 F).
Lead	(1) Basic lead carbonate, hydrofluoric acid, boric acid, glue	Using lead anodes, and bath temperatures of 77 to 105 F, fine-grained, dense deposits have been applied directly to steel surfaces.
	(2) Fluosilicate acid, lead, glue	Fluosilicate lead baths are cheaper than fluoborate solutions for large scale operations. Disadvantages are inability to deposit directly on steel, and the decomposition which occurs in the bath. Used extensively for electrorefining of lead.
Nickel	(1) *Watts type:* Nickel sulfate, nickel chloride, boric acid	Although many changes have been made since Watts' 1916 formula, fundamentally, the composition has remained the same. Licensed processes for producing bright deposits make use of the same basic formula, but use specific addition agents. The ordinary Watts bath provides a ductile, dense, dull white coating. Addition agents can be used to produce semi-bright or bright coatings.
	(2) *Chloride-sulfate solution:* Nickel chloride, nickel sulfate, boric acid	High-speed deposition has been made through the use of chloride-sulfate baths, where the nickel sulfate and nickel chloride are used in approximately the same quantities. Bright and dull coatings have been achieved at rates approximating 300 amp. per sq. ft.
	(3) Nickel chloride, boric acid	It has been reported that nickel coatings deposited from a chloride boric acid solution are fine-grained, smooth and hard. Advantages for this type of bath are listed as less power consumption, simplicity of control, wide plating range, high efficiencies, and lower susceptibility to pitting.
	(4) Nickel sulfate, ammonium chloride, boric acid	The value of the ammonium chloride, nickel sulfate, boric acid solution lies in the hardness of the coatings which are obtained. Nickel deposits of a 380 to 500 Vickers hardness can be secured.
Palladium	(1) Palladium amino nitrite, di-sodium phosphate, di-ammonium phosphate, benzoic acid	Palladium anodes are used and efficiencies of 100% are achieved. The deposits stay bright for a long time, and any cloudiness which appears can easily be buffed away.
	(2) Palladium chloride, ammonium chloride	Highly suitable for heavy deposits. 100% anode and cathode efficiencies are obtained at current densities of 10 amp./sq.ft.
Platinum	(1) *Platinum P-salt:* Ammonium nitrite, sodium nitrite, pt. diammino nitrite, ammonia	Fast coverage with fair throwing power from a high temperature bath with unlimited life. Platinum supplied as diammino nitrite.
	(2) Di-ammonium phosphate, di-sodium phosphate, chloro-platinic acid	Slow rate of deposition from a bath of short life due to accumulation of chloride. Solution replenished by additions of platinic chloride, and has to be boiled after each addition.
Rhodium	(1) Sulfuric acid, rhodium metal (2) Ortho-phosphoric acid, rhodium metal	Insoluble platinum anodes are used and the bath is maintained between 110 and 145 F. Rhodium deposits are usually applied over nickel plate, except when it is being applied over gold alloys or the other platinum metals. The phosphate type is preferred for plating of tin alloys.
Silver	(1) Potassium cyanide, potassium carbonate, brightener, silver (2) Sodium cyanide, sodium carbonate, brightener, silver	Pure silver anodes are used in silver cyanide baths operated at room temperature. The potassium cyanide solution is the most popular for commercial plating, even though it is slightly more expensive than the sodium cyanide bath.
Tin	(1) Tin sulfate, sulfuric acid, tartaric acid, glue, cresol	Tin deposits from acid solutions are whiter, but less adherent than those from alkaline baths. High efficiencies permit rapid deposition at room temperatures, and bath maintenance is relatively simple.
	(2) Sodium stannate, sodium hydroxide, sodium acetate, sodium perborate	Sodium stannate baths offer excellent throwing power, fine-grained adherent deposits. Deposition is accomplished at temperatures between 140 and 176 F.
Zinc	(1) Zinc sulfate, ammonium chloride, aluminum sulfate, licorice	Used extensively for coating wire and strip steel. High plating rate and low operating costs are advantages. Deposits are whiter but coarser-grained than those deposited from cyanide baths.
	(2) Zinc cyanide, sodium cyanide, caustic soda	Superior throwing power, finer-grained deposit. Bright deposits are achieved through the use of addition agents and are controlled through license agreements.

Here is a modern electroplating setup in which a fully automatic conveyor is used in conjunction with semi-automatic plating equipment. (Courtesy: Hanson-Van Winkle-Munning Co.)

Electroplating Theory

Although it is entirely possible to select the best coating and solution for a specific need without delving into the theories of electrodeposition, an understanding of the basic theory will often aid in the interpretation of the given data.

The passage of electricity through an electrolytic conductor is always associated with a movement of matter and its separation at the electrodes. The brilliant research work of Michael Faraday (1833) led to the discovery of the relationship between the quantity of electricity passed through the solution and the quantity of matter liberated. Stated briefly, the two laws presented by Faraday which form the basis for comprehension of the phenomena involved in electroplating advance the following:

1. The quantity of any element or group of elements liberated at either the anode or cathode during electrolysis is proportional to the quantity of electricity that passes through the solution.
2. The quantities of different elements or groups of elements liberated by the same quantity of electricity are proportional to their equivalent weights.

NOTE: *The equivalent weight of a metal is the atomic weight divided by the valence.*

For example, under given conditions, a coulomb (ampere-second) deposits 1.118 mg. of silver on the cathode. We know then that 10 coulombs will deposit 10 X 1.118 or 11.18 mg. of silver whether the total quantity of electricity is produced by the flow of 1 amp. for 10 sec. or 2 amp. for 5 sec.

Knowing the quantity of one metal, such as silver, which is liberated by a given quantity of electricity, it is possible, through the use of the second part of Faraday's law, to compute the quantity of any other metal which will be deposited by the same quantity of electricity. Since the two equivalent weights will be respectively proportional to the quantities liberated, computation is rather simple. The following equation is readily set up:

$$\frac{W_1}{W_2} = \frac{E_1}{E_2}$$

Where W_1 is the equivalent weight of the metal "Y"

W_2 is the equivalent weight of the metal "X"

E_1 is the quantity of "Y" metal deposited by the passage of a given current (the electrochemical equivalent)

E_2 is the unknown quantity of "X" metal which will be deposited by the passage of the same given current

For example, let us assume that knowing the data relative to silver, we want to find out the electrochemical equivalent of zinc for the passage of one coulomb. Using the formula above we would get:

$$W_1 = 108$$

$$W_2 = \frac{65.4}{2}$$

$$E_1 = 1.118$$

$$\frac{108}{32.7} = \frac{1.118}{E_2}$$

$$E_2 = \frac{1.118 \times 32.7}{108} = 0.339 \text{ mg. of zinc deposited by a coulomb}$$

Dividing the equivalent weight of silver, 108 grams, by the number of grams deposited through the passage of one coulomb, 0.001118 grams, we arrive at the figure 96,550, which is the number of coulombs

Table VIII—Electrochemical Equivalents

Calculated on Basis of 100% Cathode Efficiency

Metal	Atomic Weight	Valence	Thickness in In. of 1 oz./sq. ft.	Grams Deposited Per Amp. Hr.	Amp. Hr. Per Sq. Ft. to Deposit 0.001 In.
Cadmium	112.41	2	0.00139	2.0968	9.73
Chromium	52.01	6	0.00169	0.3233	51.8
Cobalt(ous)	58.94	2	0.00135	1.100	19.0
Copper(ous)	63.57	1	0.00134	2.371	8.89
Copper(ic)	63.57	2	0.00134	1.186	17.8
Gold(ous)	197.2	1	0.00068*	7.356	6.2
Gold(ic)	197.2	3	0.00068*	2.450	18.6
Indium	114.76	3	0.00182*	1.427	12.0
Iron(ous)	55.84	2	0.00153	1.042	17.9
Lead	207.22	2	0.00106	3.865	6.9
Nickel	58.69	2	0.00135	1.095	19.0
Palladium	106.7	2	0.00116*	1.990	13.5
Platinum	195.23	4	0.00062*	1.821	27.8
Rhodium	102.91	3	0.00106*	1.280	22.9
Silver	107.88	1	0.00126*	4.025	6.2
Tin(ous)	118.70	2	0.00164	2.214	7.8
Tin(ic)	118.70	4	0.00164	1.107	15.6
Zinc	65.38	2	0.00168	1.182	14.3

These figures are for 1 troy oz. per sq. ft.

it takes to deposit the gram equivalent weight of silver. This quantity, called the faraday, will liberate an equivalent weight in grams of any other element, and is equal to 26.8 amp.-hr.

Theoretically, therefore, the gram equivalent weight of any metal is deposited upon the cathode for each faraday. Due to numerous conditions, however, such as current leakage, solution variations and the like, 100% cathode efficiency is not always achieved. The amount of metal which is actually deposited, divided by the amount theoretically deposited, is called the cathode efficiency. Knowing the electrochemical equivalents of the various metals being plated, and knowing as well the cathode efficiency which should be obtained from the particular type of bath being used, it is possible to control the thickness of the deposit and to double check on the efficiency of the solution being used.

Table VIII lists the electrochemical equivalents of the various metals as calculated on the basis of 100% cathode efficiency. Table IX lists the average efficiencies obtained from common electroplating baths. Used together, these two tables are a valuable reference guide for the foreman electroplater.

Table IX—Average Cathode Current Efficiencies of Common Plating Solutions

Metal	Type of Bath	Usual Cathode Efficiency—%
Cadmium	Cyanide	88-95
Chromium	Chromic acid-sulfate	12-16
Copper	Acid sulfate	97-100
Copper	Cyanide	30-60
Copper	Rochelle-cyanide	40-70
Cobalt	Acid sulfate	95-98
Gold	Cyanide	70-90
Indium	Cyanide	30-50
Indium	Fluoborate	30-50
Indium	Acid sulfate	70-80
Iron	Acid chloride	90-98
Iron	Acid sulfate	95-98
Lead	Fluoborate	100
Lead	Fluosilicate	100
Nickel	Acid sulfate	94-98
Silver	Cyanide	100
Tin	Acid sulfate	90-95
Tin	Stannate	70-90
Rhodium	Acid phosphate	10-18
Rhodium	Acid sulfate	10-18
Zinc	Acid sulfate	99
Zinc	Cyanide	85-90

Preparation for Electroplating

Surface cleanliness and preparation is an extremely important phase of electroplating. No matter how well regulated the solution, nor how careful the operator, if the surface has not been properly prepared to receive the plating, poor adherence with corresponding inefficient corrosion protection will result.

The field of preparation falls into three main groups: namely, mechanical preparation and cleaning, chemical cleaning, and, finally, chemical preparation. Although it is not the intention here to go into detail about these groups which make up the immensely important preparation cycle, a short discussion of the scope of each is in order.

Mechanical cleaning and surface preparation includes the various methods for grit blasting, tumbling, wire-wheeling, and polishing. It is invaluable for the removal of heavy scale, or for the dressing up of a surface to a relatively smooth or high polish finish. The value of the surface finish prior to electroplating should be evident when we remember that the plated coating will reflect the type of finish upon which it has been deposited.

Chemical cleaning includes the removal of various oils, greases, stains, dirt particles, etc., and is differentiated in the mind of the writer from chemical preparation, in that there is no interaction with the metal sur-

face. For the removal of light greases and oils various organic solvent dips have been employed, and recently there has been an alert interest in vapor degreasing. The vapors from boiling trichlorethylene or perchlorethylene have proved an invaluable tool to the electroplating industry, doing a faster, cleaner job than most solvent dips. Strong alkali cleaners are used for the removal of more stubborn contamination, and, where necessary, an electrolytic cleaning unit is included. The electrolytic cleaner is nothing more than the strong alkali cleaner designed so that the work can be made the anode and cathode alternately. This provides an agitation and a cleansing action which has resulted in superior cleaning.

Under the heading of chemical preparation we can consider the various types of pickling acids and assorted acid dips which etch the surface to increase adhesion qualities of the metal being deposited. Acid pickling is done with sulfuric, hydrochloric and combinations of nitric and hydrofluoric acids, and is an essential treatment for the removal of heat treat scale, rust and other difficult-to-remove surface contaminants. The choice of the pickle depends on a number of factors, including the material being plated, the metal being deposited, the quantities in production, etc. Generally, however, for the electroplating of steel parts, sulfuric and hydrochloric share the popularity; sulfuric because it is cheap, and hydrochloric because it gives a smut-free surface and does not attack the base metal as readily as does sulfuric.

The following tabulation sums up methods of cleaning and preparation which are necessary toward the securing of satisfactory electroplates.

I. Preparing the metallic base
 A. Clean mechanically
  1. grit blast
  2. polish to required smoothness
 B. Clean chemically
  1. organic solvents (vapor or dip)
  2. alkali cleaners
  3. electrolytic alkali cleaners
 C. Prepare chemically
  1. acid pickle
  2. special acid dips

NOTE: *Rinsing operations are advisable between the various stages.*

II. Preparing the nonmetallic base
 A. Mechanical cleaning and roughening
 B. Chemically clean to remove grease and oil and all other contaminants
 C. Render surface conductive (any of the following)
  1. chemical reduction of a metal on the surface
  2. apply powdered graphite or metal which has been added to suitable binder or lacquer
  3. spray on molten metal
  4. evaporate or distill metals in a high vacuum chamber so that they are condensed on the surface
  5. transfer the metal under the influence of high voltage and in a high vacuum (cathode sputtering)

NOTE: *The importance of preparing a plastic base for proper application of electroplated coatings is included here because the tendency to plate plastics is becoming widespread both from the decorative and the industrial point of view. Details of the methods for making the surface conductive provide study in themselves and will not be elaborated upon here.*

Equipment for Electroplating

Although a full discussion of equipment and materials for the plating room should include reference to cleaning, polishing, pickling and surface preparation requirements, our discussion here will be limited to those facilities utilized by the electroplating operation only. These fall naturally into two main categories: (1) the tanks themselves, and (2) racking and handling equipment.

The selection of the material from which to construct the plating tanks depends upon the solution employed, the materials available, temperature requirements, and established costs. The materials which have been suggested for plating tank construction include wood, iron (or steel), stoneware, concrete, various plastics, rubber and glass. A number of experimental tanks of small sizes have been built from a whole line of materials having specific properties and resistances needed for a particular installation, but for production tank work the above listed materials enjoy the widest application.

By far the greatest number of plating tanks have been constructed of wood, and lined with a variety of materials for specific purposes. The general use of wood is due to its availability and the fact that it can be fabricated and repaired by plant personnel. Wood is not resistant to plating solutions, but it has been used successfully for acid baths provided asphalt, tar, rubber or sheet lead linings are carefully installed. Cypress and redwood are in widest use for tanks, especially for rinse tanks where they can be used unlined. The use of wood tanks for alkaline solutions, even when the tanks are lined, is to be discouraged because even occasional contact with alkalies is sufficient to start deterioration. All wooden tanks should be painted on the exterior, preferably with a bituminous paint.

Steel or iron tanks are widely employed for alkaline solutions, but they must be constructed of heavy gage metal to resist the effect of corrosion from without. Recent progress in the application of rubber linings has made steel and iron tanks suitable for acid solutions as well. The main disadvantage of all metal tanks is their conductivity, which permits possible short-circuiting. In the selection of rubber linings, moreover, it is important to avoid compounds from which organic constituents can be extracted by the bath. Such materials can be particularly harmful in certain bright nickel solutions.

Vitrified stoneware is extremely resistant to dilute acids and has been increasing in usefulness around plating plants. Stoneware is attacked by hydrofluoric acid, however, and for these solutions lead lined tanks are recommended. In addition, stoneware is attacked by dilute alkalies, and is therefore not suitable for cleaning solutions or for alkaline plating baths. The chief advantages of stoneware tanks are their resistance to the chemical action of many solutions, their low electrical conductivity, and their high thermal conductivity. Their principal disadvantage seems to be their relative fragility, which renders them liable to breakage and chipping.

Reinforced concrete tanks have been used for plating and electrotyping. They can be built of cheap, readily available materials and in any size or shape desired. However, they are usually not portable and must therefore be destroyed if it is decided to rearrange the plant layout. Concrete is not very resistant to acids or alkalies and, consequently, the tanks must be lined.

For small experimental tanks, glass, hard rubber and enameled iron tanks have been used. Advantages of the glass tanks are visibility, non-conducting properties, and excellent chemical resistance. The hard rubber small tanks are suitable only for room temperature application. They have excellent resistance to acid, but not to alkaline solutions. Enameled iron has practically the same resistance to acids and alkalies as has glass, but has the disadvantage inherent in the possible chipping of the enamel. Vitreous enameled tanks are in wide use for gold and platinum plating.

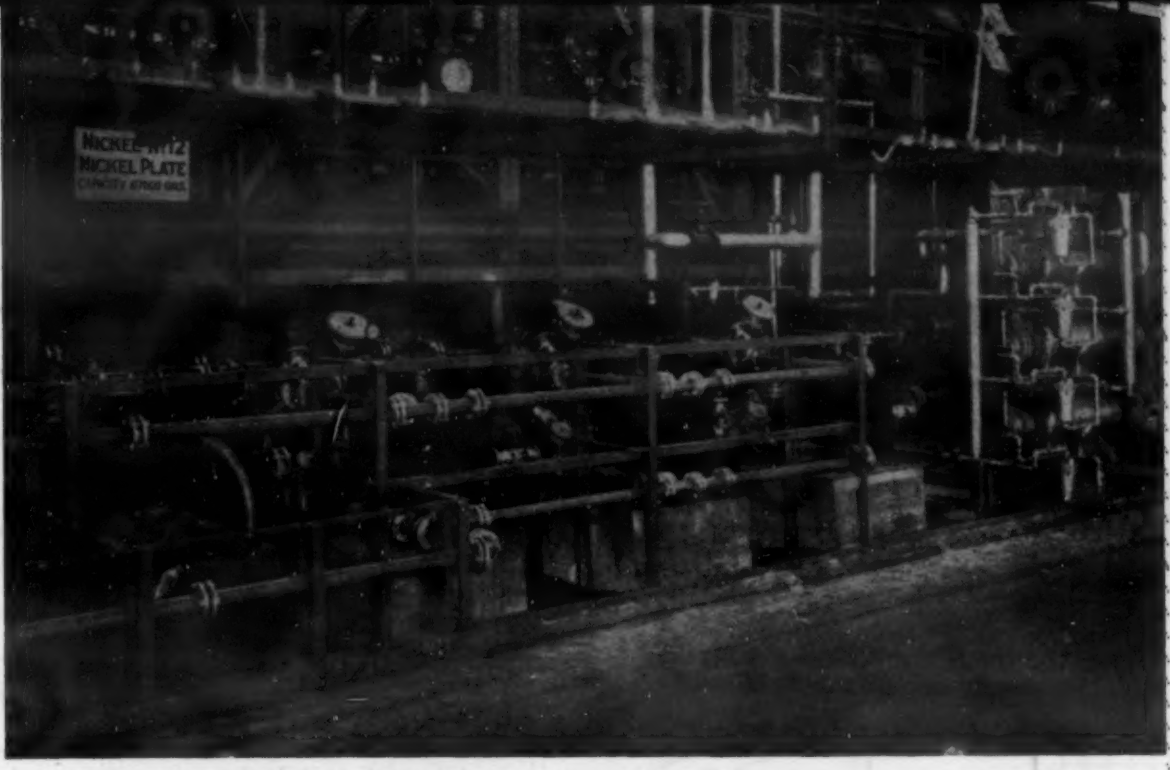
The problem of handling equipment for plating operations is not so much one of material, as it is one of design, and the choice here is dependent to a large extent on the size of the installation, the quantity of material processed, and the money available. The basic decision involves the choice between still tanks or barrels, and is resolved through the evaluation of a number of factors. Both are essential in the average plating room, but the quantity of each depends upon the type of parts being processed.

In order to be plated, parts have to be suspended on racks which permit the passage of current. Since the contact portion of the rack and the part is small, as compared with the overall size of the rack, specially designed rack coatings have been developed which insulate all portions of the rack except the contact area. This saves the useless deposition of the plated metal on the rack, and eliminates the time waste incurred in deplating non-insulated racks which have been heavily coated with the metal being deposited.

The design of the rack is important, too, because the use of carefully designed racks saves time in hang-up and reduces the number of rejects. Modern rack design allows for build-up in almost every size and shape through the use of small detachable units.

After the parts have been racked, the problem of how to get them to the plating tanks must be faced. In the majority of plants, each rack is taken over individually and hung from the cathode bar (after all cleaning and pickling operations have been completed, of course). Some of the more modern plants have installed overhead cranes which permit loading and racking directly on the cathode bar, and lifting and positioning of the completely loaded bar in whatever tank is required.

The latest in modern developments consists of a completely automatic plating unit, in which the racks are hung on the cathode bar at the racking station, and the bars are then automatically taken by the conveyor unit through all the cleaning, pickling and plating tanks.



Good electroplating depends upon many things, not the least of which is a clean solution. In this illustration is shown the arrangement of filters and heat exchangers in a huge electroplating plant. (Courtesy: George L. Nankervis Co.)

Electrical Equipment

All electroplating operations require direct current voltages of small values, and these values are not available from the distribution lines of light and power companies. The standardized high voltage currents must therefore be suitably altered before they can be used for electrodeposition.

At the present time, motor-generators are most widely used to supply the necessary low voltage current. Where the power supply consists of alternating currents, an induction or synchronous motor of suitable horsepower, speed, voltage phase and frequency is selected to drive the direct current electroplating generators. If the power supply is direct current, a d.c. motor of suitable horsepower, speed and voltage is selected for the job.

The use of metal plate rectifiers for electroplating is of fairly recent application, and it forms an alternative method to motor generators for converting high-voltage a.c. to low voltage d.c., which is suitable for electrodeposition. The rectifier unit comprises a transformer wound to reduce the voltage of the a.c. supply, a plate rectifier to convert low voltage a.c. to low voltage d.c., and the necessary control mechanism. In spite of the fact that rectifiers are relatively new, they are rapidly replacing motor generators in many installations. Some of the reasons for the rapid extension of the rectifier into the electroplating field are as follows:

1. Space savings — rectifier equipment occupies approximately 10% of the factory floor space usually required by motor generators.
2. Less power consumption—
   a. instantaneous start-and-stop
   b. maintained efficiency
   c. use of individual units permits elimination of tank rheostats and rheostat power loss.
3. Weight savings — rectifiers are substantially lighter and less cumbersome than motor generators, thereby substantially lowering floor loads.
4. Ease of installation—the light weight and compact units make installation relatively simple, and facilitate movement within the factory.

It is expected that as time goes by these advantages of space, weight and power savings will translate themselves into a considerably wider use of rectifier equipment. At present, three general types of plate rectifiers are being used: copper oxide, magnesium-copper sulfide and selenium, each of which possesses specific advantages.

It has been stated that low voltage direct current is required for electroplating operations, and up until very recently this statement would not have needed any clarification or amplification. Something new has been added, however, so that inclusive statements, such as this fundamental truism, do not tell the whole story.

In addition to the direct current applied, attempts have been made to superimpose a 60-cycle alternating current potential; by this means it is intended to increase the allowable current density and speed up the plating operation. At the present writing there is insufficient evidence to justify any broad statements as to benefits derived from superimposed a.c. on d.c. Experiments in eliminating the negative portion of the alternating current cycle, and utilizing the pulsed direct current of the same frequency as the a.c., thereby increasing the total number of coulombs passed in a given time, have resulted in faster plating rates. Here too, however, there are not enough experience data to warrant statements as to benefits obtained.

The latest development in the field of current source is known as periodic reverse-current plating. In this process the plating current is reversed briefly at short intervals, resulting in the deplating of unsound and inferior metal deposited during the preceding plating cycle. It is possible, through this method, to produce a plate that is considerably smoother than the surface of the base member to which it is applied, and thus substantially reduce customary finishing costs.

This, too, is still largely in the experimental stage, but from the evidence advanced to date, it looms as a process worthy of much consideration in the future of electrodeposition.

Testing of Coatings

Electroplating, like any other industrial branch of science, has its own set of standards through which we judge the value of the finished product. In order to choose the most suitable coating for a specific application, we must resort to test data which have been compiled and tabulated from a wide variety of tests. After our choice is made, we want to be able to test our own product to make sure we are getting what has been specified. The only way this can be accomplished is through the use of standardized tests.

Although at the present time the electroplating industry is still short of definitive specifications, each year sees the incorporation of new ones and a determined effort to raise quality standards throughout the field. Tests have no value unless they are standardized so that the results can be duplicated; and the test data have no value unless we understand what was being tested, how it was done, and under what conditions.

The following table lists the most common test methods for investigating the most important properties of electroplated coatings:

Table X—Testing Plated Coatings

Property Being Tested	Test Methods and General Notes
Thickness	(1) Average thickness determined by dissolving the coating without affecting the base metal. The part is weighed before and after, and a direct reading of the weight of the deposit for the given area is taken from the loss of weight shown. The average thickness is then computed from the coating weight.
	(2) Local thickness a. Microscope—involves cutting an appropriate cross section. It destroys the specimen, but is in wide use because of its accuracy. b. Chord method—this involves cutting through the coating with a file or precision grinding wheel, and then measuring the width of the cut. It destroys the coating but does not affect the specimen. Although relatively accurate, it does not compare with the microscopic method.
	c. Chemical immersion—involves periodic dipping in neutral solution of copper sulfate until an adherent copper coating is produced. Used for checking distribution of zinc coatings on steel.
	d. Chemical spot tests—involve timing one drop of reagent until it completes solution of plating at given point. Must be closely controlled even for fair accuracy.
	e. Chemical drop tests—involve timing a stream of drops of a given reagent until penetration of the plated coating is observed. Not an accurate method.
	f. Chemical jet tests—involve timing a continuous fine stream of the reagent directed on the surface until penetration of the base is observed.
	g. Electrochemical methods—involve measuring the time required for a coating to dissolve anodically at a specified current. Accurate.
	h. Magnetic methods—These methods are based upon the fact that nonmagnetic coatings upon a magnetic metal decrease the magnetic attraction of that metal in direct proportion to the thickness. The advantage of these methods lies in the fact that they do not destroy the base metal or the coating, and that they are rapid. Although not so reliable as the microscopic method or the electrochemical method, they are being widely used for spot checking thickness in the plating room.
Adhesion	(1) Jacquet Method—a thick coating is applied to a flat strip so that one end of the coating can be readily detached and held in a tensile machine. The force required to pull the coating from the strip of fixed width is recorded as the measure of adhesion.
	(2) Ollard method—a thick coating is applied to one end of a cylinder, and then turned on a lathe so as to leave a sharp external shoulder. A hole is then drilled in the center, and the specimen so placed that the shoulder rests on a steel collar. Load is applied to the center by a small plunger and the force required to detach the ring of deposit is considered the measure of adhesion.
	(3) Bending, hammering and stretching tests are utilized with adhesion ratings given as "good" or "poor."
Corrosion Resistance	(1) Exposure tests—sample panels are exposed to prescribed conditions and results are recorded. Valuable when data are specific and comparative tests have been made.
	(2) Salt spray tests—used widely during the war for acceptance standards on zinc and cadmium. Requires close control of all variables. Used as a porosity test.
	(3) Ferroxyl test—used to determine porosity of plated coatings. Is not sufficiently quantitative or reproducible. Depends upon surface application of a solution containing a corrosive agent, a ferricyanide to produce a blue color with any ferrous compound formed by corrosion, and a jelling agent such as agar.
	(4) Hot water tests—used to detect pores in nickel coatings on steel—not reliable.
Tensile Strength	Tensile properties such as elastic limit, tensile strength and elongation are measured by producing strips of plated metal detached from the base upon which they had been plated, and then testing these strips in standard machines. Strips are produced by plating on a surface which has been previously treated with graphite or other separating medium.
Hardness	Hardness measurements of plated coatings are difficult to make because of the effect of the base metal and the general lack of agreement as to the real meaning of hardness. Brinell number, Vickers numbers, Rockwell numbers and other indentation and scratch hardness tests have been conducted for research purposes. The results are valuable, but the tests require laboratory control methods to assure accuracy.
Reflectivity	(1) Total reflecting power—for the visible spectrum, the following reflectivities have been recorded: Silver—90-95% Aluminum—90-95% Rhodium—72% Chromium—66% Nickel—62%
	(2) Brightness—the relation between the specular and diffuse reflection. No simple system has been developed for measuring brightness, but a number of methods have been devised which offer good comparative values.

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MATERIALS & METHODS Engineering File Facts

NUMBER 161
June, 1948

METHODS: Cleaning
MATERIALS: Monel

Pickling Monel Metal

Contaminant	Solution	Temp. F	Time	Remarks
Grease, Oils, Fats and Fatty Acid Combinations	Vapor degreasing using trichlorethylene or perchlorethylene, or solvent immersion using kerosene, carbon tetrachloride or the solvents used for vapor degreasing, may be used for preliminary cleaning, but must be followed by alkali cleaning.			
	10-20% solution of equal parts of: sodium carbonate trisodium phosphate	180-200	15-30 min.	Sodium hydroxide may be used in place of the sodium carbonate.
Tarnish	(1) Water 1 gal. Nitric acid 1 gal. Common salt ½-¾ lb.	70-100	5 sec.	Prewarm parts in hot water before dipping in solution #1. Use hot water rinses between dips.
	(2) Water 1 gal. Nitric acid 1 gal.	70-100	5 sec.	
Reduced Oxide	Water 1 gal. Sulfuric acid ¾ pt. Sodium nitrate ½ lb. Common salt 1 lb.	180-190	30-90 min.	Scrubbing parts with pumice, with alternate dipping, will shorten time.
Oxide Film or Scale	(1) Water 1 gal. Hydrochloric acid ½ gal. Cupric chloride ¼ lb.	180	20-40 min.	Cupric chloride hastens reaction, but may be omitted. Hot water rinses required between solutions 1 and 2.
	(2) Water 1 gal. Sulfuric acid 1/10 gal. Sodium dichromate 1 1/10 lb.	180	5-10 min.	
	Lamp black 1 lb. Fuller's earth 10 lb. Hydrochloric acid 3 gal. Nitric acid ½ pt. Cupric chloride 1-2 lb.	70-100	20-60 min.	For parts too large to be immersed. Hot water hosing required. Lime paste as neutralizer may be used if hot water is not available.
Embedded Iron Particles	Hydrochloric acid 1½ gal. Water 1½ gal.	Room	15-30 min.	Rinse thoroughly before and after.
	Lamp black 1 lb. Fuller's earth 10 lb.	Room	1-12 hr.	Apply by brush on parts too large for immersion. Hose off using warm water.

Prepared by Edward Rosen and George Black

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MATERIALS & METHODS Engineering File Facts

NUMBER 162
June, 1948

MATERIALS: Monel Metal
METHODS: Finishing

Grinding, Polishing and Buffing of Monel

	Name of Operation (and No.)	Grit	Wheels	Compound	Speed—Surface Ft. per Min.	Finish
	Grinding (1)	#24	Rubber-bond grinding wheel	—	8000-9000	—
Polishing	Roughing (2)	#60 #80	Cotton fabric sewed sections. Sections glued together to give desired width. Soft cushion face.	—	6000-7500	Rough grind
Polishing	Dry Fining (3)	#100 #120			Do.	Commercial grind
Polishing	Greasing (4)	#150	64-68 unbleached sheeting. Spiral sewing-sections glued together to give desired width. Softer cushion face than needed. For "Roughing" or "Dry Fining."	Polishing tallow or #180 emery grease cake	Do.	Fine grind
Polishing	Greasing (5)	#180	—	Do.	Do.	Fine grind
Polishing	Grease (6) Coloring	#200 #220	88-88 unbleached sheeting. Same construction as for operations #4 and #5—or quilted sheep skin wheel.	Polishing tallow or "F" emery grease cake	Do.	Fine scratch
Polishing	Grease (7) Coloring	—	88-88 unbleached sheeting. Loose spiral-sewed sections or loose disk wheel.	"F" emery grease cake	Do.	Fine scratch
	Brushing (8)	—	Tampico wheels.	"F" emery grease cake or "Grout"	1200-3000	Scratch brush or satin
	Bobbing or Sanding (9)	—	Walrus leather wheel. When two operations required. Second usually with medium density felt wheel.	"Grout"	5000	—
Buffing	Cutting-Down (10)	—	Same as operation #7.	Tripoli	8000-9000	Bright
Buffing	Coloring (11)	—	Same as operation #7.	Aluminum oxide buffing compound (white)	10,000	Bright
Buffing	Coloring (12)	—	Loose-disk buff or 88-88 unbleached sheeting or canton flannel.	Chromium oxide buffing compound (green)	10,000	Mirror
Special Finishes	Greaseless Method (13)	—	Same as operation #7.	Greaseless compound	5500	Scratch brush or satin
Special Finishes	Bobbing (14)	—	Walrus leather wheel.	Pumice with oil	5000	Butler or satin
	Cleaning (15)	—	Canton flannel cloth (hand operation).	Venetian lime (Whiting)	—	—

Prepared by Edward Rosen, Brooklyn, N. Y.

MATERIALS & METHODS

DIGEST

A selective condensation of articles — presenting new developments and ideas in materials and their processing—from foreign journals and domestic publications of specialized circulation.

Edited by H. R. CLAUSER

Wartime Heat Treating Developments

Significant findings of American and German wartime research and experience in heat treatment of steel and steel alloys are contained in nine reports just issued by the Office of Technical Services, Department of Commerce. They are listed briefly below:

"Corrosion Resistance of Annealed Versus Embrittled 27% Chromium-Iron Alloy in Boiling 65% Nitric Acid (PB-62829)"—Alloys of 27% chromium with iron studied for resistance to boiling 65% nitric acid when in the annealed state.

"The Effect of Temperature Upon the Hardness of Croloy 27 (PB-62853)"—Describes temperature gradient test conducted for the purpose of accurately determining the temperature range that will affect the physical properties of Croloy 27. The test was conducted for 400 hr., in which time the test bar was subject to gradually decreasing temperatures from 1570 F to 380 F.

"Effect of Long Time Heating on Hardness and Structure of 27% Chromium-Iron Alloys as Determined by the Gradient Bar Heating Test (PB-62830)" — Describes temperature gradient tests. The tests reported were conducted on identical specimen material for 1000 and 1600 hr.

"Absorption of Hydrogen During the Annealing Process, Its Influence on the Formation of Flakes and Brittleness (PB-64725)" — Written in German. Part I covers the combined effect of hydrogen and stresses in the formation of flaky flaws, dependence of flake formation on annealing temperature, influence of cooling speeds, and the connection between martensitic transformation and flake formation. Part II deals with the danger of flake formation due to hydrogen absorption in the preparation of steel, and the influence of segregations, impurities, and various hydrogen-containing gases. Part III covers impairing of expansion and reduction in area due to hydrogen annealing, changes in stability properties of unalloyed and low alloyed steels due to hydrogen absorption during annealing, properties of austenitic steel during annealing in hydrogen, and the behavior of hydrogen containing steels at low temperatures.

"The Temporal Course of Strength Loss During the Annealing of Cold-Rolled, Deep-Drawn Steel (PB-65051)"—In German. Presents results of experiments undertaken with the purpose of finding the influence of glowing on tensile properties of cold-rolled, deep-drawn steel.

"Direct Determination of the Speed of a Temperature Change, Especially Cooling Speed, by Electrical Differentiation (PB-65099)"—In German. Describes experiments which have shown that differences in the temperature in cooling metals in annealing processes are sufficient to produce thermoelectric voltages by which the cooling speed can be measured by charging a condenser in parallel with the thermocouple.

"Measurement and Regulation of Temperature in an Annealing Plant of a Southern Germany Instrument Factory (PB-4600-S 70)"—In German. Is a reprint of an article in the *"Siemens-Zeitschrift,"* April-June 1942. The article, by Fritz Faller, introduces its topic by explaining the necessity of exact temperature, time and cooling treatment of high-grade steel, especially when conditions prevent the use of desirable quantities of critical metals (tungsten) for alloys; and describes the annealing equipment as used in a German precision instrument factory.

"Induction Heating: Selective Annealing, Tempering and Strain-Relieving (PB-49265)"—Briefly and non-technically discusses the use of high-frequency induction heating for tempering and annealing. The high-frequency converter used in experimental work is described, and several cases which serve to indicate various aspects of induction heating are described and illustrated.

"Annealing, Pickling, Washing and Liming of Rolled Steel Wire (PB-44662)"—Discusses economical and technically satisfactory methods of scale removal from wire. Control of sulfur and carbon in the furnace gases, selection of most satisfactory pickling methods, and proper liming and elimination of hydrogen brittleness are emphasized.

Chromated Protein Films for Protecting Metal Surfaces

Chromated protein coatings for protecting metals—especially zinc, iron, brass and aluminum—during outdoor storage in mildly corrosive atmospheres have been developed by A. Brenner, G. Riddell & R. Seegmiller, National Bureau of Standards. The technical details of these coatings are reported in the *Journal of the Electrochemical Society*, March, 1948.

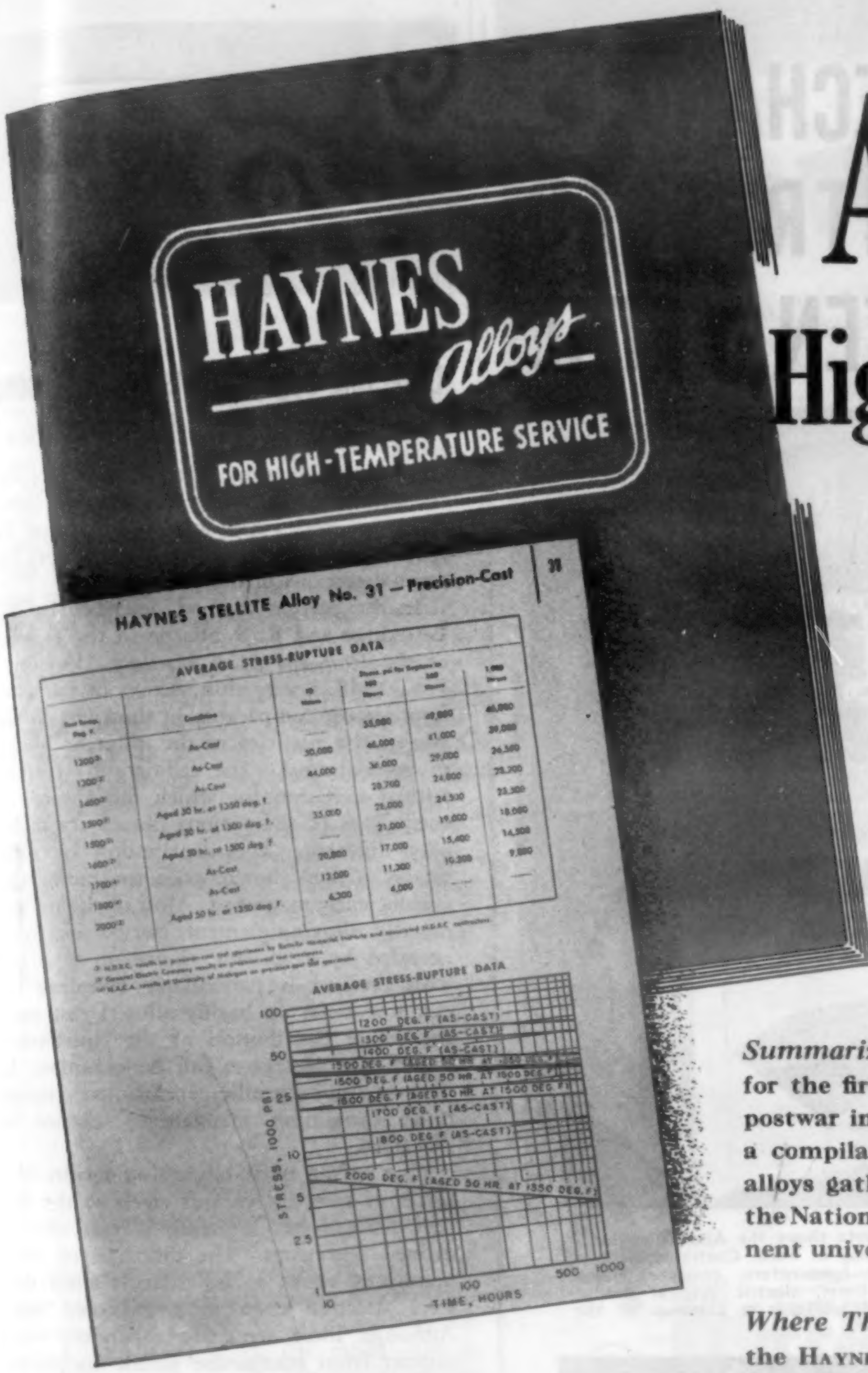
The protective value of such films is somewhat better than that afforded by chemical surface treatments, and is much superior to that of corrosion-inhibited oils and waxes. The metallic surface to be coated is first dipped in casein, albumin, or gelatin; the resultant film is then impregnated with chromate, which both hardens the film and inhibits corrosion.

The principal constituents of the chromated protein films are a corrosion inhibitor for the metal, a protein which acts as a vehicle for the inhibitor, a hardening agent, and a bactericide to prevent putrefaction of the protein.

The chromated protein films are yellow and, unless opaque pigments have been added, are transparent. Their flexibility and adhesion are sufficient to prevent cracking or separation when the metal is bent. They are not injured by heating to 300 F. Thickness depends principally on the concentration and viscosity of the protein solutions, varying with the type of protein up to about 0.0002 in. This is in contrast to the proprietary chromate films, which usually are not more than 0.0003 in. thick.

When freshly prepared and hardened, the films are almost insoluble in water and are so hard that they cannot be scratched with the finger nail. However, the films may be quickly removed from metal parts by application of an alkaline solution, such as 5% sodium hydroxide.

The protein solutions are fairly stable for long periods. While chromated protein films are superior to direct phosphate or chromate coatings or to oil films for corrosion prevention, their life is less than that of suitable paint coatings. They are more effective on large, regular surfaces than on the sharp edges and corners of small objects like nuts and bolts, where the film tends to pull away.



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Detecting Segregations and Inclusions in Steel by Micro-Radiography

Micro-radiography offers a new tool for the investigation of segregations and inclusions in steel. Although used before in special cases, it has not been satisfactory for normal sections of most alloys.

In the present method described by W. Betteridge and R. S. Sharpe in the *Journal of the Iron and Steel Institute* (English), Feb., 1948, a very thin section of the alloy is prepared, comparable in thickness to the size of the particles of the different phases to be identified. The radiograph is taken with a radiation for which the absorption coefficients of the various phases are markedly different. The distribution of these phases is then shown when the radiograph is sufficiently magnified. Most of the normal metallic alloying elements can be selectively revealed by a suitable choice of radiation. This method is particularly revealing for cast materials. In highly alloyed cast steel, the actual distribution of the constituents within the segregates can be obtained. In general, non-metallic inclusions (except those containing manganese) cannot be identified.

One of the most interesting results of a series of tests on various steels is the fact that manganese frequently forms sharply defined segregates. The diffusion of these segregates seems to be difficult since they were detected even in over-heated steel. Although these areas are apparently quite distinct from manganese sulfide inclusions, the sharpness of their boundaries suggests that they may not be true segregates. It is believed that these areas are not merely regions of high-manganese solid solution but in fact are actual separate phases which are not soluble in the matrix.

Improvement of Machinability in High Phosphorus Gray Cast Iron

It is well known that high phosphorus gray iron castings have poor machinability. This is particularly true whenever high phosphorus castings are machined at high cutting speeds. In a paper (Preprint No. 48-21) by W. W. Austin, Jr., delivered before the 1948 annual meeting (May 3-7) of the *American Foundrymen's Association*, methods of improving the machinability of these castings were described.

The results of an investigation showed

DIGEST

that definite improvement can be obtained by desulfurization of the base iron, with and without alloy additions. The base iron had the following composition: 3.54 carbon, 2.56 silicon, 0.69 manganese, 0.069 sulfur, and 0.65% phosphorus. It was found that desulfurization alone would produce appreciable improvement in the machinability rating of the base iron (that is, an increase of 24% over that of the untreated iron).

Significant improvement can be attained by a combined treatment involving sodium carbonate desulfurization followed by zirconium alloy addition. Specific conditions arising from the resulting low sulfur content and the zirconium addition give rise to an improvement of 40 to 50% in the machinability of the base iron with but little alteration of its composition other than sulfur. This treatment is believed to be commercially practicable and can be carried out at an estimated cost of less than $2.50 per ton of treated iron.

Stabilization of Austenitic Stainless Steel

Austenitic stainless steels, of the 18:8 type are particularly susceptible to intergranular corrosion if subjected to moderately elevated temperatures—in the range 700 to 1400 F—and then are either simultaneously or subsequently subjected to corrosive conditions. Experience has shown that the steels may be stabilized against intergranular embrittlement by the addition of titanium or columbium, usually in conjunction with a stabilizing heat treatment.

A diversity of opinion has existed, however, as to the relative amounts of titanium or columbium necessary, the injurious effect of carbon content, and the necessity for stabilizing heat treatments. The National Bureau of Standards set out to study the factors affecting the stabilization of the 18:8 type of steels, and a technical account of the work is given in the *Journal of Research*, April, 1948, by J. S. Rosenberg & J. H. Dorr.

Considering the steels which contained no stabilizing elements, the tests showed that all were vulnerable to intergranular attack. Decrease in carbon content, however, decreased the degree of vulnerability.

In columbium- and titanium-bearing steels, carbon content within the range of 0.06 to 0.13% had no influence upon the resistance to intergranular attack except as it influenced the ratios of columbium to carbon or titanium to carbon. Steels varying in carbon content but having similar ratios of

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either columbium or titanium to carbon had approximately the same degree of susceptibility to intergranular attack regardless of the total carbon content. The steels showed greater resistance to attack when annealed at 1800 F than when annealed at 1957 F.

Stabilizing heat treatments at 1600 F had a negligible effect upon the resistance to intergranular embrittlement of the columbium-treated steels so that these steels carrying a sufficiently high ratio of columbium to carbon may be used without giving them a stabilizing heat treatment. However, the performance of the titanium-treated steels carrying the higher ratios of titanium to carbon was markedly improved by such treatments.

Recent French Work on Interrupted Quenching

A clear and definite answer cannot yet be given to the question whether interrupted quenching imparts mechanical properties which are equivalent, inferior or superior to those obtained with the usual martensitic quench. Some interesting French views on this subject are reported in an article by G. Delbart, appearing in the English publication *Metal Treatment,* Winter, 1947-1948.

The comparison of the mechanical properties of tempered martensite and tempered intermediate structures is not simple. A contributing factor is the fact that there is not merely one but numerous intermediate structures. In many cases, the best properties are obtained by martensitic quenching, but only to the extent that it does not give rise to micro-cracks. Lower bainite may give high mechanical properties approaching those found in tempered martensite which does not contain micro-cracks. On the other hand, an equal improvement by treatments producing coarser and more heterogenous intermediate structures is not to be expected.

Interrupted quenching has the advantage of avoiding, to a large extent, internal stresses and micro-cracks. Where there is a possibility of the formation of micro-cracks in conventional heat treatments, as in water quenching, interrupted quenching ought to give a distinct improvement in mechanical properties, particularly impact. The difference should be less if the interrupted quench is compared with oil or air quenches.

It is obviously better to form a martensitic structure by isothermal quenching (martempering) than by direct quenching. If isothermal quenching is conducted so as to avoid the internal stresses and micro-cracks possible in direct quenching, it ought normally to give better results than direct quenching.

DIGEST

New Method of Resistance Welding Light Alloys

One factor that has tended to hinder the development of aluminum has been the need for special equipment for resistance welding. With the older methods of resistance welding, machines of much larger output than those required to weld steel of equal thickness have to be used. Also, the oxide film on the aluminum has to be removed before welding. Furthermore, frequent changes of electrodes are necessary to avoid sticking to the copper electrodes. With seam welding the weld is not always continuous, even under the best conditions.

A new method has been evolved which is described by E. J. Keefe & L. B. Wilson in *Light Metals* (English), March, 1948. In this method steel strips of definite thickness are interposed between the electrodes and the aluminum. The passage of current generates about four times as much heat in the steel as in the aluminum. Therefore, the aluminum is heated by conduction to a temperature just below that needed for welding, before it reaches the position between the electrodes where the weld is made. This preheated aluminum can then be welded to give a uniform, continuous seam weld of high efficiency. If the correct welding pressures are used and a fine adjustment of the current can be made, the steel does not stick to the aluminum.

Perfectly gas-tight seam welds with tensile strengths up to 92% that of the parent metal have been obtained with this method. The most important advantage is the elimination of the necessity for large output machines for resistance welding aluminum.

The new process shows some promise for magnesium, although the weld strengths obtained up until now have been only about 48% those of the parent metal.

Light Alloy Piston Materials

Most pistons in England are made from aluminum alloys. A. Schofield & L. M. Wyatt in *Metallurgia* (English), Feb., 1948, give some important facts about the proper selection of aluminum alloys for piston applications. In choosing a piston alloy, it is first necessary to decide whether low cost, hot strength, thermal conductivity, bearing properties or low expansion is the most important factor.

Service temperatures, which affect the choice, depend on the type of piston. The essence of good piston alloy development is to keep the softening temperature high

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while retaining high strength at lower temperatures. Actual failures in the hot areas are infrequent and are nearly always caused by thermal stresses. For resistance to these, high thermal conductivity, low thermal expansion and high elongation are more important than hot strength.

Wrought alloys have higher thermal conductivity and lower friction than cast alloys. Ring-groove, wear is difficult to tie down to any given property; but the aluminum-silicon alloys are better than the aluminum-copper-nickel-magnesium alloy, presumably due to the hard silicon particles in the matrix. Under very bad abrasive conditions, service equal to that of cast iron with only a small sacrifice in weight may be obtained by the use of an austenitic cast iron insert.

When the service necessitates exceptional properties, it is best to forge the piston. The heat treatment should represent the best possible compromise between maximum hardness and fatigue strength and freedom from internal stress and dimensional stability.

Consideration of the mechanical properties of the alloys indicates the best choice for each type of piston: aircraft—pre-worked wrought aluminum-copper-nickel-magnesium alloy; large Diesel—cast aluminum-copper-nickel-magnesium; high-duty car—wrought-low-expansion alloy; low-duty car (where cost is important)—cast low-expansion alloy; transport Diesel—pressed from cast blank in low expansion or aluminum-copper-nickel-magnesium alloy.

Impact Extrusion of Light Metals

When aluminum was first substituted for lead and tin in impact extrusions, 98 to 99% aluminum was used until an increasing number of rejections was experienced. It was soon found that the best results were obtained with annealed, fine grained 99.5% + aluminum. In cases where the part was not subsequently annealed and where surface finish was unimportant, coarse grained material increased the percentage yield. In addition to the large production of aluminum extrusions, attention parts requiring higher strength.
was turned to aluminum alloys for some

An interesting investigation of aluminum alloy extrusions was conducted by H. A. J. Stelljes in Germany and is reported in *Metallforschung* (German), Nov., 1947. The first attempt was the production of cap nuts from an aluminum—3% copper—magnesium alloy. Again annealed, fine grained material was best. Either pressed

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or rolled blanks could be used, but the shape of the blank was important. The extruded parts could be hardened in the usual way and the necessary machining could be done after hardening.

A comparison with cap nuts made by machining from bar stock and by hot forming showed the extruded nuts had a finer grain size and were consistently stronger. Annealed, fine grained aluminum-magnesium-silicon alloys proved satisfactory for extruding into more complicated shapes due to their better malleability as compared with the aluminum-copper-magnesium alloy.

Extrusion tests were made on cast blanks of various secondary aluminum casting alloys to see if the preliminary hot working could be eliminated. With proper treatment, they proved suitable for impact extrusion. Annealed blanks extruded better than those in the as-cast conditions. Although for some purposes there was little difference among the various types, the best over-all results were obtained in the alloys having the most uniform structure as-annealed.

Materials Engineering in Germany

A very interesting report that tells of the materials engineering practices in Germany has been issued by the *Office of Technical Services, U. S. Department of Commerce.* The report was prepared by B. F. Shepherd, and is based on his inspection of German plants manufacturing rock drills, compressors, pumps, valves, and other accessories.

In contrast with American practice of materials engineering, German manufacturers, at least in this field, follow a set formula in ordering and handling their materials. The system is personalized and semi-secret. Engineers use metal handbooks and order by brand name, or leave the responsibility for selecting the proper material to the suppliers' metallurgists. The report points out that the high cost of materials compared with the cost of labor is probably responsible for the German habit of paying more attention to design than to metal specifications.

Materials engineering in Germany, the report concludes, is kept within the province of top technical workers. Subordinates are supposed to do what they have been told without knowing the why or wherefore. As a result, most operations are routine so far as metallurgy is concerned. No attempt is made to have the workman technically understand the peculiarities of the materials he uses.

New MATERIALS AND EQUIPMENT

Manual Unit Developed for Hidden Arc Welding

Advantages of welding with the hidden arc flux process are well known. A recent development in this field by the *Lincoln Electric Co.*, Cleveland 1, is manual equipment for semi-automatic welding.

The manual equipment is a self-sufficient, portable unit, providing all the necessary welding current and auxiliary power plus the automatic wire feed mechanism and controls. The basic element of the unit is a standard 600-amp. welder which can be used for straight manual welding as well as semi-automatic welding. Mounted on the welder is a compact unit containing the wire reel, feed mechanism, drive motor and voltage controls. A special cable to which is attached a cone shaped welding gun completes the equipment.

The aluminum cone shaped welding gun holds 3½ lb. of flux, which is dispensed by gravity through a hardened nozzle in sufficient amount to cover the arc as the weld is made. The nozzle, which is insulated from the rest of the gun, also introduces the welding current to the wire and straightens the wire as it is fed through.

The unit uses a 5/64-in. dia. electrode wire to provide high degree of flexibility to the cable and ease of operation in handling the gun. The wire is automatically fed to the work through the flux that is deposited from the gun. A constant arc voltage is maintained by automatic controls independently of the height of the gun above the work. The height of the gun determines only the amount of flux that will be deposited over the arc.

The arc is started by simply touching the electrode to the work through the flux, which automatically starts the wire feeding at the proper rate for the current being used. When needed for tack welding or finishing short welds, it is possible to switch over to using manual welding with the machine without any additional adjustments.

A ½-in. plate can be welded in a plain butt weld, one pass each side, without edge preparation, with the manual hidden arc welding equipment.

New Sintering Method Improves Magnetic Material

General Electric Co., Pittsfield, Mass., have announced a method of sintering their permanent magnet material, Alnico 5, which permits the design of intricate shapes with higher external energy than has been heretofore possible. The material is especially adaptable where small powerful magnets having high magnetic properties are required and is expected to find extensive use in the electronic, electrical, instrument, and novelty industries.

The sintering process is said to permit the economical production of small sized parts which are finer grained, less brittle. The material has unusually high tensile properties and can be produced with smooth surfaces and close dimensional tolerances. The fine structure of the material also is said to eliminate crystal pick-outs and pitting.

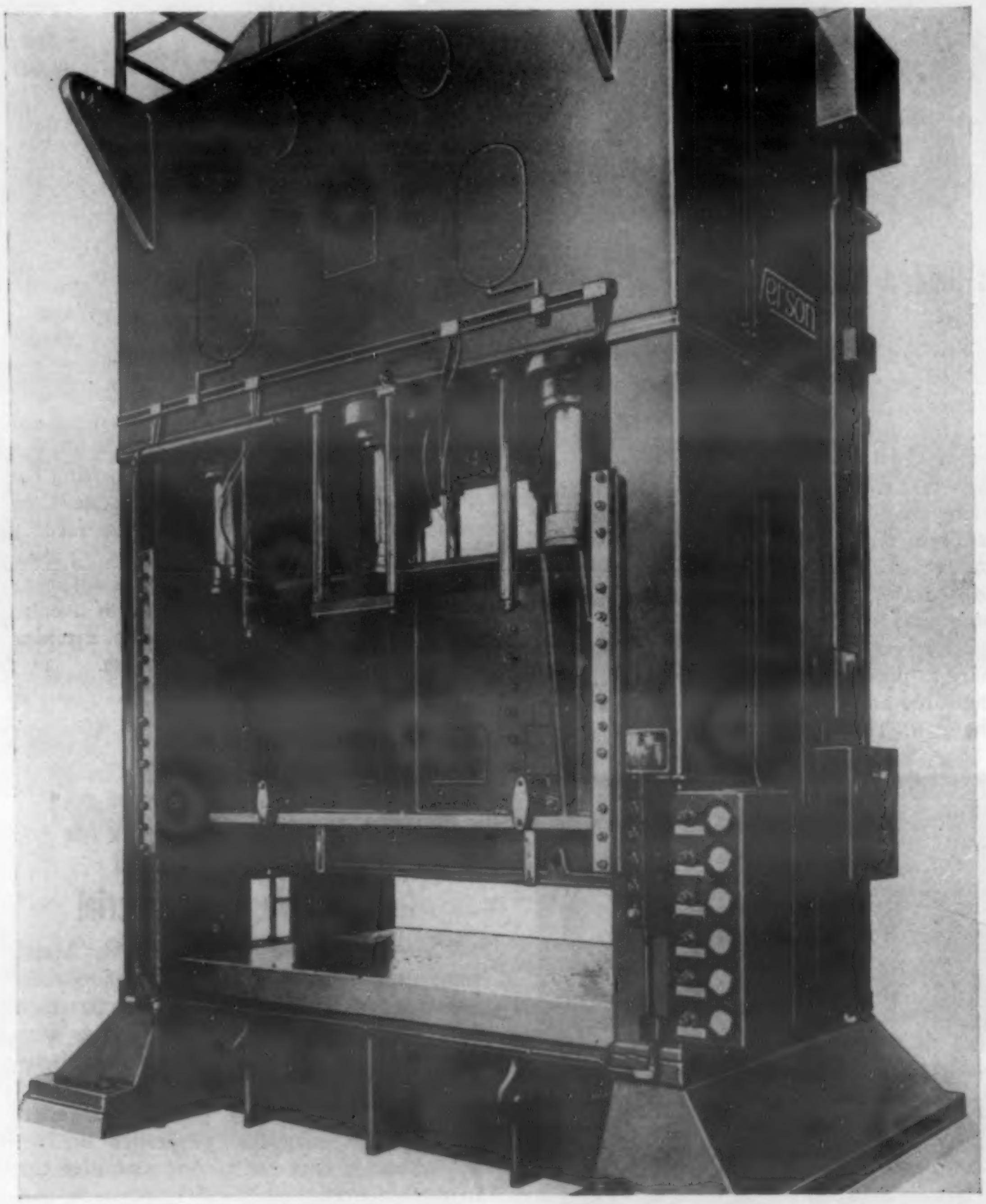
The material has a residual induction of 10,000 gauss and a coercive force of 575 oersteds. Its guaranteed available minimum energy is 3,500,000 guass-oersteds for most sizes and shapes. These properties apply only in the direction of heat treatment.

Deep Drawing Press Combines Mechanical and Hydraulic Systems

Two principles of force application—mechanical and hydraulic—have been combined in the double action deep drawing press announced by *Allsteel Press Co.,* 1355 E. 93 St., Chicago 19. The press is said to have the high productive capacity of the mechanical drawing press plus the adjustable blankholder features previously found only in hydraulic presses.

Among the advantages claimed for this combination mechanical-hydraulic press are: (1) Increased production on deep draw; (2) instantaneous adjustment of pressure by valves and direct reading gages at any pressure point on the blankholder; (3) blankholder is self-adjusting for any thickness of stock and automatically compensates for minor variation in stock thickness during normal operation; (4) no need for the use of shims; and (5) no tool-damaging impact between blankholder, stock and die.

Press cycle, including the delayed action return of the bed cushions, is fully automatic and controlled by means of electric push button and selector panel. The press is available in a wide range of bed sizes and tonnage capacities for ferrous and nonferrous metals.



This double action deep drawing press employs mechanic and hydraulic principles of force application.

Carbide Tool Developments

A new line of standard carbide tools has been announced by *National Tool Salvage Co.,* 5611 Epworth Blvd., Detroit. The line includes core drills; reamers; twist drills, both tipped and solid; slotting cutters; hardened steel drill; end mills and face and shell end mills.

A new counterbore, with cutting edges at two ends instead of just one, has been developed by the *Plan-O-Mill Corp.,* 1511 E. Eight Mile Road, Hazel Park 20, Mich. The new tool is available in a complete range of sizes in high-speed steel or with tungsten carbide inserts. Both single and multi-diameter styles are offered, with or without pilots. Two types of holders—collet and sleeve—furnish a positive drive with runout of less than 0.002 in.

A new carbide drill for drilling hardened H. S. Steel registering as high as 66 on the Rockwell "C" scale is available from *National Tool Salvage Co.,* 6511 Epworth Blvd., Detroit. The new drill incorporates a special grind which is said to result in faster cutting and less heat, with the result that the drill holds up longer and produces smoother holes true to size without annealing the work.

● A new leak-proof, ejector type, light duty resistance welding holder has been announced by *P. R. Mallory & Co.,* Indianapolis 6, Ind. The holder is arranged so that the water circuit forces water against the head of the electrode tip regardless of length, and the water circuit is sealed so that there is no leakage to create a rust problem on the work.

Industrial Heater Designed as Complete Package Unit

In addition to the heater with improved design features, the Midget Utility Air Heater, introduced by *Gas Appliance Service, Inc.,* 1211 Webster Ave., Chicago 14, Ill., also contains fan, motor, drive, safety devices and temperature controller.

The heater is direct fired for maximum heating efficiency; and since it is ideal for heating drying rooms and small industrial ovens, the unit can be employed by most industries. Typical applications include: baking lacquers and enamels on metal ware; baking varnish on coils and armatures; curing rubber products; drying of paint, paper, soap pads and statuary; and various uses in the food processing field.

Five features of this unit permit a heating capacity of 125,000 Btu per hr. and precise control of temperatures to 350. They are: (1) the bricklined combustion chamber allows complete combustion of gases, (2) the burner has good turn-down range that gives proper temperature control, (3) the fan has a capacity of 1000 cu. ft. of air per min., (4) the hot air can be recirculated for better fuel economy, and (5) both the burner output and air volume can be regulated for progressive temperature control and air circulation.

Besides being low in cost, easy to install and simple to operate, the unit functions with temperature controls of either the indicating or nonindicating type, and safety devices that shut off the gas supply in case of flame power or fan failure.

Versatility Featured in New Twin Miller

A new twin miller, particularly for light duty work where two surfaces can be milled in a single pass, has been developed by the *W. H. Nichols Co.*, Waltham 54, Mass. The machine has two opposed independent geared milling heads powered by pan cake type motors, and each has available 15 spindle speeds from 55 to 2080 rpm.

Each milling head is adjustable in three planes: horizontally by means of slides and

This double-spindle miller is particularly useful for light-duty applications.

set screws; vertically; and transversely by feed screws with direct reading micrometer dials. The maximum height of spindle centerline above table is 12 in., minimum height is 1½ in. The maximum distance between spindle noses across table is 16 in., the minimum distance is 4 in.

The 8½-in. by 34-in. table is pneumatically powered by a solenoid-operated air cylinder and travels a maximum of 12 in., with a 9-in. hydraulically controlling cutting stroke. The machine requires 4 ft. by 5 ft. floor space and is 55 in. in height.

Multi-Recording Print Wheel Prevents Crossing of Records

An improved skip numeral print wheel has been marketed by the *Brown Instrument Div., Minneapolis-Honeywell Regulator Co.*, 2926 Fourth Ave., Minneapolis, Minn. When used with strip chart electronic recorders, this wheel permits symmetrical and well-defined multiple measurement records.

Field experience tests over the past several months show that the new skip numeral print wheel eliminates a crossing of records and a super-position of numerals of any one record. The print wheel utilizes the same basic system of plus and numerical identification; it also staggers the numeral locations for different records, permitting use of slower chart speeds. Slower chart speeds in turn permit a substantial chart economy while maintaining clarity and permanency of recorded measurements. This is particularly true when such speeds are used in conjunction with standard charts made for electronic recorders.

MEEHANITE castings are turned to closely controlled curves in big milling machines. The finished casting holds lenses which are diamond-ground and then polished.

Polishing tool made of MEEHANITE metal holds a number of lenses which are checked at regular intervals during polishing against master testing lens (in worker's right hand)

For Flawless Perfection Argus Lenses are ground on

MEEHANITE® CASTINGS.

ARGUS, INCORPORATED, Ann Arbor, Michigan, Manufacturers of fine cameras and precision optical instruments, has high standards of perfection which each component part must maintain. In such units lens surfaces must be ground for extreme accuracy and flawless smoothness.

Meehanite lens tools contribute much to the achievement of this goal. Illustrated are two production steps in the use of Meehanite castings at Argus. For such castings only the maximum in density, freedom from porosity and warpage will meet the requirements.

Because of the metallurgical and technical knowledge applied to each step in the manufacture of Meehanite castings, exacting service conditions can be met—the *right* combination of properties provided.

For that "extra" in quality which your product demands—remember

MEEHANITE FOUNDRIES

American Brake Shoe Co.	Mahwah, New Jersey
The American Laundry Machinery Co.	Rochester, New York
Atlas Foundry Co.	Detroit, Michigan
Banner Iron Works	St. Louis, Missouri
Barnett Foundry & Machine Co.	Irvington, New Jersey
E. W. Bliss Co.	Hastings, Mich. and Toledo, O.
Builders Iron Foundry Inc.	Providence, R. I.
H. W. Butterworth & Sons Co.	Bethayres, Pennsylvania
Continental Gin Co.	Birmingham, Alabama
The Cooper-Bessemer Corp.	Mt. Vernon, Ohio and Grove City, Pa.
Crawford & Doherty Foundry Co.	Portland, Oregon
Farrel-Birmingham Co., Inc.	Ansonia, Connecticut
Florence Pipe Foundry & Machine Co.	Florence, New Jersey
Fulton Foundry & Machine Co., Inc.	Cleveland, Ohio
General Foundry & Manufacturing Co.	Flint, Michigan
Greenlee Foundry Co.	Chicago, Illinois
The Hamilton Foundry & Machine Co.	Hamilton, Ohio
Johnstone Foundries, Inc.	Grove City, Pennsylvania
Kanawha Manufacturing Co.	Charleston, West Virginia
Koehring Co.	Milwaukee, Wisconsin
Lincoln Foundry Corp.	Los Angeles, California
The Henry Perkins Co.	Bridgewater, Massachusetts
Pohlman Foundry Co., Inc.	Buffalo, New York
Rosedale Foundry & Machine Co.	Pittsburgh, Pennsylvania
Ross-Meehan Foundries	Chattanooga, Tennessee
Shenango-Penn Mold Co.	Dover, Ohio
Standard Foundry Co.	Worcester, Massachusetts
The Stearns-Roger Manufacturing Co.	Denver, Colorado
Traylor Engineering & Mfg. Co.	Allentown, Pennsylvania
Valley Iron Works, Inc.	St. Paul, Minnesota
Vulcan Foundry Co.	Oakland, California
Warren Foundry & Pipe Corporation	Phillipsburg, New Jersey
Washington Machinery & Supply Co.	Spokane, Washington
E. Long Ltd.	Orillia, Ontario
Otis-Fensom Elevator Co., Ltd.	Hamilton, Ontario

"This advertisement sponsored by foundries listed above."

"Meehanite Means Better Castings" **MEEHANITE**®

PERSHING SQUARE BUILDING • NEW ROCHELLE, N. Y.

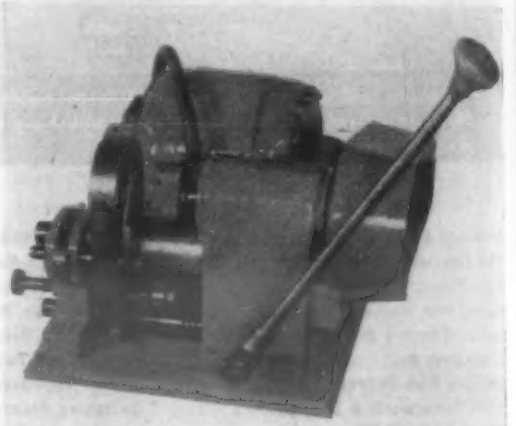
Tube Deburring Machine Employs New Type Chuck

A manually operated, bench type tube and rod end finishing machine is now being offered by the *Pines Engineering Co.*, Aurora, Ill. The machine design embodies a new type mechanical chuck and chuck closing mechanism that holds securely any length tube, pipe or rod up to 2 in. in dia. With the work firmly held, deburring, chamfering and facing can be completed separately or simultaneously in a single pass of the machine.

Work clamping is accomplished automatically by closing the chuck jaws, which are equipped with a split type insert to fit individual tube or rod diameter. Controlled clamping pressure of the insert against the outer wall of the piece prevents distortion and marring.

It is possible to deburr, chamfer and face tube and pipe ends, or to center drill or form rod ends at the rate of 500 to 1000 ends per hr. Production depends upon the size and length of the stock, cut taken and the type of material being machined.

The design and operation makes it well adapted for use in those plants fabricating tubular stock and parts. These include the automotive and aviation industries, refrigeration, metal furniture, air conditioning, hydraulic, bicycle, toy, sporting goods and



Simple chucking arrangement, easy adjustments and rapid semi-automatic cycle makes this machine useful for production and tool room work.

many other important manufacturers of metal and plastic parts.

The tube and rod end finishing machine is equally efficient for occasional or production work in machine shops. It is used extensively for centering rods and bars and because of its flexibility and multiple uses becomes an important tool in such shops.

● A new automatic electrically powered buffing and polishing machine is capable of finishing 800 parts per hr., according to its makers, the *Vanott Machine Corp.*, 218 Colgate Ave., Buffalo, N. Y. The machine has eight spindles on a revolving head which indexes at pre-determined speeds. Each spindle is provided with a chuck, or a gripping device, individually designed for each shape, to hold the work being buffed or polished.

New Developments in Drilling Equipment

Mueller Industries, 4755 N. Rockwell St., Chicago 25, Ill., has introduced a new universal parts holder for drilling, milling, tapping, threading, counter boring and similar operations. This fixture can be operated either manually or automatically and is adjustable for location and pressure, thus providing fast, accurate production.

Teletronics Laboratory, Westbury, N. Y., has a unique precision instrument for rapidly drilling small holes with accuracy. By means of a thermal motor feed and automatic electronic control circuits, the surface of the work to be drilled can be located quickly and precisely and the drilling depth held to close tolerance. Both the danger of breaking even the smallest drill, and visual observation of the drilling operation, have been virtually eliminated.

The *Cleveland Tapping Machine Co.,* Hartville, Ohio, now manufactures a new Model EO Cleveland Lead Screw Tapping Machine that will tap single holes up to ½-in. National Course Thread in mild steel. By using multiple heads, up to 8 No. 6-32 or four ¼-in. holes can be tapped. Either manual or automatic operation is possible. Where the work permits automatic handling, indexing feeds, cross slides and hopper feed may be combined with automatic cycling to provide a 100% automatic operation.

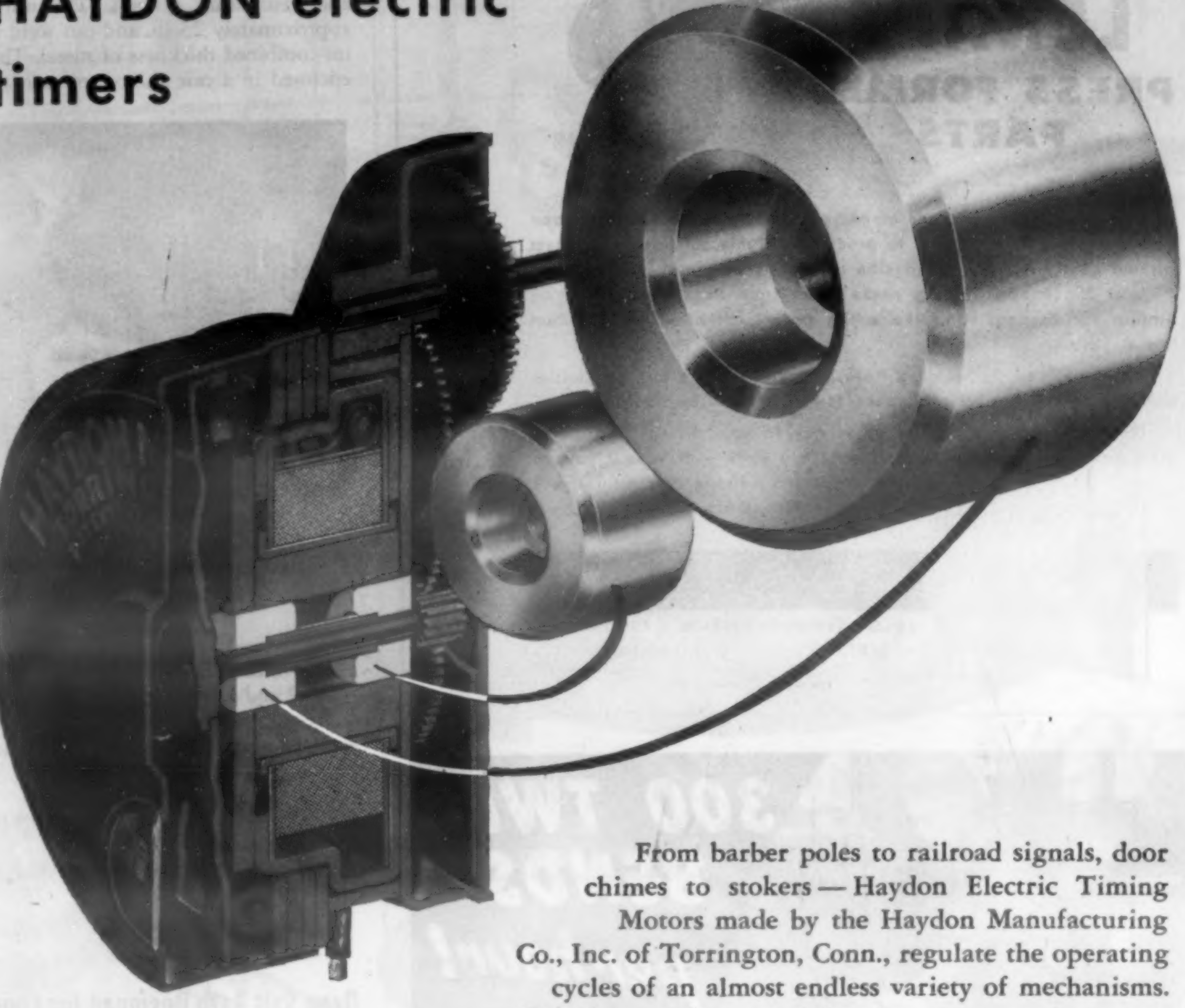
The *Universal Vise & Tool Co.,* Parma, Mich., has introduced a Model No. 8 safety work holder that provides a quick and easy method for securing drill press work on tables where there is no provision for clamping with bolts. The holder can be kept on the press table at all times; raises and lowers with the table; and locks with only a quarter turn of the handles. The holder jaws open the full width of the bar to accommodate 11-in. work. If desired, these jaws can be removed instantly. Similarly, the work holder itself can be removed from the press merely by loosening two set screws.

Bronze Sheet Rolled from Centrifugally Cast Billets

A new development in the production of aluminum bronze rolled sheet is the use of centrifugally cast slabs for rolling in preference to the more commonly used statically cast ones. This centrifugally cast material is said to result in a sheet that is sound, solid, flaw-free and uniform; no porosity, slag inclusions, pipes, striations, or laminations are found in the finished strip, sheet or plate.

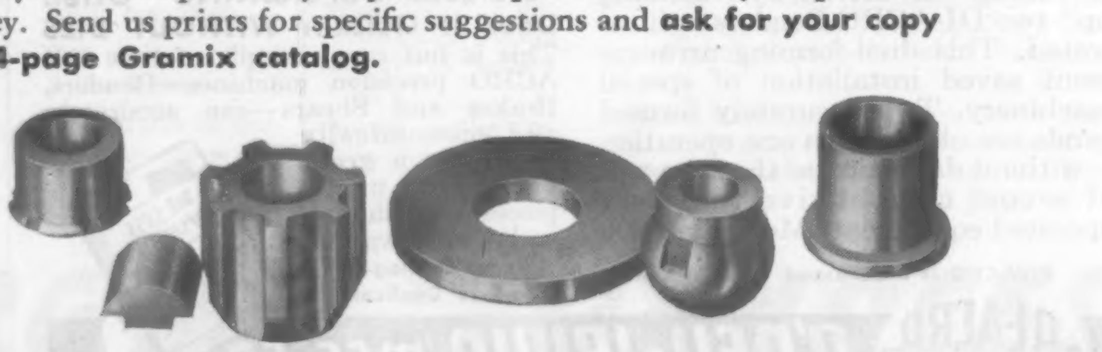
This bronze rolled sheet and plate, produced by *Ampco Metal, Inc.,* Milwaukee 4, Wis., may be obtained annealed for fabrication purposes where corrosion-resistance is important, or it may be obtained unannealed and specially processed for applications where wear resistance is essential, such as for gibs, ways, liners and similar parts in metal working equipment.

GRAMIX BEARINGS help assure dependable, smooth operation for HAYDON electric timers



From barber poles to railroad signals, door chimes to stokers — Haydon Electric Timing Motors made by the Haydon Manufacturing Co., Inc. of Torrington, Conn., regulate the operating cycles of an almost endless variety of mechanisms. Gramix powder metal bearings *are an important reason* for the dependability of these timing devices. Two Gramix bearings are installed on the timer motor shaft, separated by an oil reservoir. Being porous, they meter lubricant to the shaft as needed, *assuring smooth and quiet operation.* Being tough, strong, and longwearing, they eliminate bearing replacement costs as well as minimize maintenance problems. And since they are economically mass produced by die-pressing powdered metal to exact size and shape, they cost less than machined bearings . . We can produce Gramix bearings, thrust washers, and other powder metal parts to *any practical size and shape* and with finishes that require no costly machining. Many types may be impregnated with oil to make further lubrication unnecessary. Gramix parts may improve the performance of your products and save you money. Send us prints for specific suggestions and **ask for your copy of the 264-page Gramix catalog.**

GRAMIX



THE UNITED STATES GRAPHITE COMPANY • SAGINAW, MICHIGAN

Hand Spot Welder Is Self-Operating and Portable

A new lightweight portable spot-welder is available from *Greyhound A. C. Arc Welder Corp.*, 606 Johnson Ave., Brooklyn 6, N.Y.

The spot-welder is handy for welding jobs on window frames, sky-lights, display signs, kitchen equipment, wire fences, blowers and ventilating systems. The unit weighs approximately 23 lb. and can weld up to 1/8 in. combined thickness of metal. The unit is enclosed in a cast aluminum casing with an integral aluminum handle. The protruding copper arms are available in three lengths—6, 12 and 18 in.

This handy manual spot-welder is ideal for repair shops and sheet metal shops.

Available in either 220- or 110-v. units, each portable spot-welder is supplied with 10 ft. of cable.

Deep Salt Bath Designed for Long Work

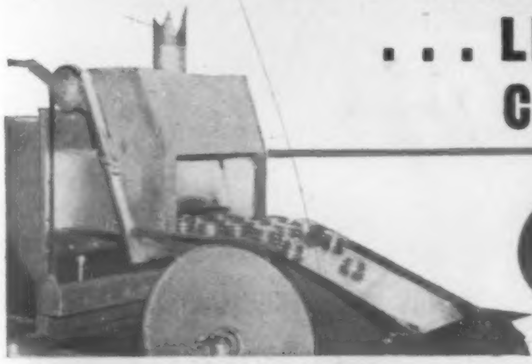
Salt bath heat treating for work of exceptional length has been restricted due to the lack of satisfactory deep bath furnace designs. The *Ajax Electric Co.*, Philadelphia 23, has now developed a new salt bath for heat treating in the temperature range of 300 to 2400 F, which permits the work, regardless of its length, to be hung vertically. Compared with horizontal loading in conventional furnaces, the vertical loading assures control over distortion, simplifies the fixtures and work-holding devices, and reduces the floor space requirements.

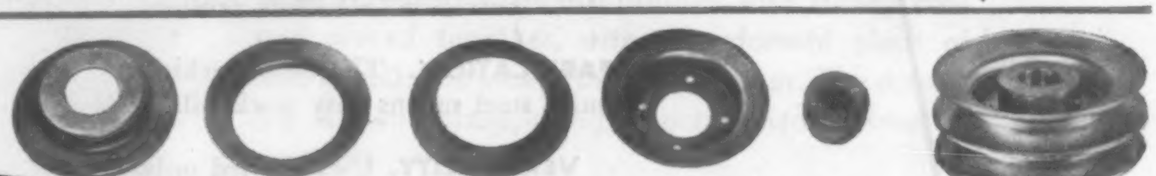
These furnaces are similar to this company's standard units except that the electrodes are inserted through the side walls and are completely immersed in the bath. In the event that the salt should freeze because of power interruption, control equipment failure, or any other reason, no damage is done. Shrinkage of the salt due to freezing drops the level of the bath so that the electrodes are exposed a few inches above the surface of the solidified salt and the bath can readily be restarted by melting a small salt area between the closely-spaced electrodes.

For deep furnaces, several pairs of elec-

HERE'S HOW...

... LINDBERG BRAZING FURNACE CUTS PRODUCTION COST $38.50 per hr.





FIVE PARTS BRAZED IN SINGLE OPERATION

T. E. NELSON, Vice President, Nelson Manufacturing Corporation says: "We're constantly redesigning cast and drop forged parts for production by brazing. In every case so far we have been able to knock costs down plenty."

Nelson Manufacturing Corporation, Pontiac, Michigan, manufacturers of pulleys, sheaves, and other stamped metal products, braze 385 power lawnmower pulleys per hour in Lindberg Mesh Belt Conveyor Furnace. (435 lbs. net; 750 lbs. gross.) Production costs are 10c less per pulley!—a saving of $38.50 per hour over cost of producing pulleys as castings.

Check this "Before and After" story of Brazing advantages.

BEFORE	AFTER
Belt grooves and center hole had to be finish machined with cast pulley—a costly operation.	No machining required for brazed pulley.
Cast pulley weighed 2 lbs. 2 ozs.	Brazed pulley weighs only 18 ozs.—reduces overall weight of mower 1 lb.
Rejects due to casting flaws ran at 6%.	Brazed pulley rejects—None.

Greater Production

Lindberg Brazing furnaces are designed to produce 1½ times greater production per sq. ft. of heating chamber area than conventional brazing furnaces.

Versatile

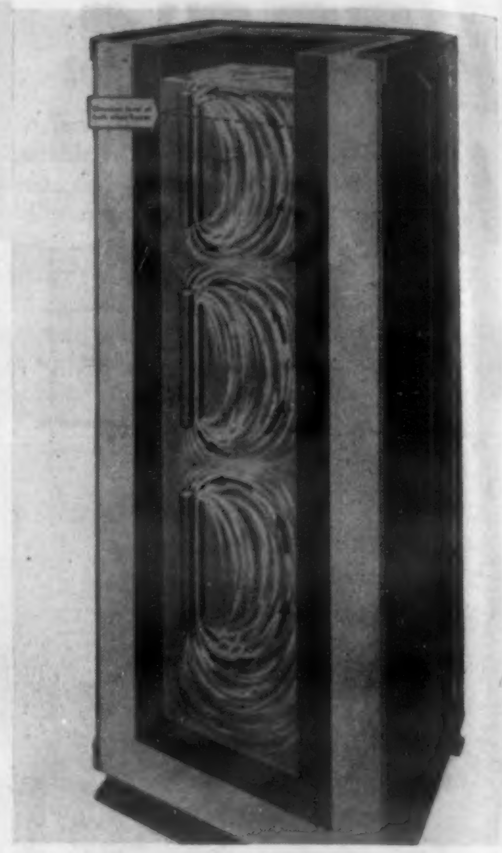
Lindberg Brazing furnaces can also be used for low temperature silver brazing—bright annealing—sintering of powder metals.

No Production Delays

Lindberg Furnaces are designed so that heating elements can be changed in a matter of minutes without cooling furnace.

Bulletin 210 "Lindberg Continuous Production Brazing Furnaces" is available on request. Lindberg Engineering Co., 2451 W. Hubbard St., Chicago 12, Illinois.

LINDBERG FURNACES



Cross-section view shows details of the new deep salt bath furnace design.

trodes are cascaded, one above the other. In restarting, the top pair melts the salt within its zone and presents molten salt to the electrodes directly beneath and so on down to the bottom of the bath. Because melting of a solidified bath is from top to bottom, there is no danger of creating sealed-in pressure at the bottom while the top is still frozen.

Cut-Off Wheel Has Reinforced Construction

The development of a new reinforced type of cut-off wheel has been announced by *Norton Co.,* Worcester, Mass. It was developed, according to the company, to meet the demand from nonferrous foundries for a wheel that would be tough and hard to break, have long life, and a fast cut. The wheel's unique design and reinforced construction serve to give it a high safety factor against breakage plus a fast cutting action and a low rate of wear.

The sides of the wheel present a file-like surface which is said to greatly enhance the wheel's cutting action. At cutting speeds which reach a maximum of 16,000 ft. per min. at the periphery of the wheel, the concentric rows of molded "teeth" in themselves impart an effective cutting action, supplementing the normal cutting action of the cutting points and edges presented by the "Alundum" abrasive cutting grains in the periphery of the wheel.

This wheel is available at present in three standard diameters, 14 in., 16 in., and 20 in., and in two thicknesses, 5/32 in. and 3/16 in. The 3/16-in. thick wheels are recommended for unusually severe jobs requiring maximum wheel strength.

New Interferometer Measures Flatness of Surfaces

The Williams Plano Interferometer is a new type of instrument for measuring flatness of surfaces. This high-precision device was developed by Dr. W. Ewart Williams, company consultant, *Bausch & Lomb Optical Co.*, Pasadena, Calif. When in operation, the unit sets up shadow-like bands of interference in light reflected between its master optical flat and the object being tested. Surface accuracy of the master optical flat is one-millionth of an in.

The new instrument has three basic advantages over former interferometers. First of all, it operates at various room temperatures. Secondly, operation and adjustment are simple; where it previously took several hours to bring an instrument into proper adjustment, it can now be done in less than 10 sec. Next, the master optical flat is never brought in contact with the object under inspection; this eliminates the possibility of scratching or distorting the flat. Finally, surfaces with as much as a 4-in. recess can be inspected to determine the quality of areas that formerly could not be reached.

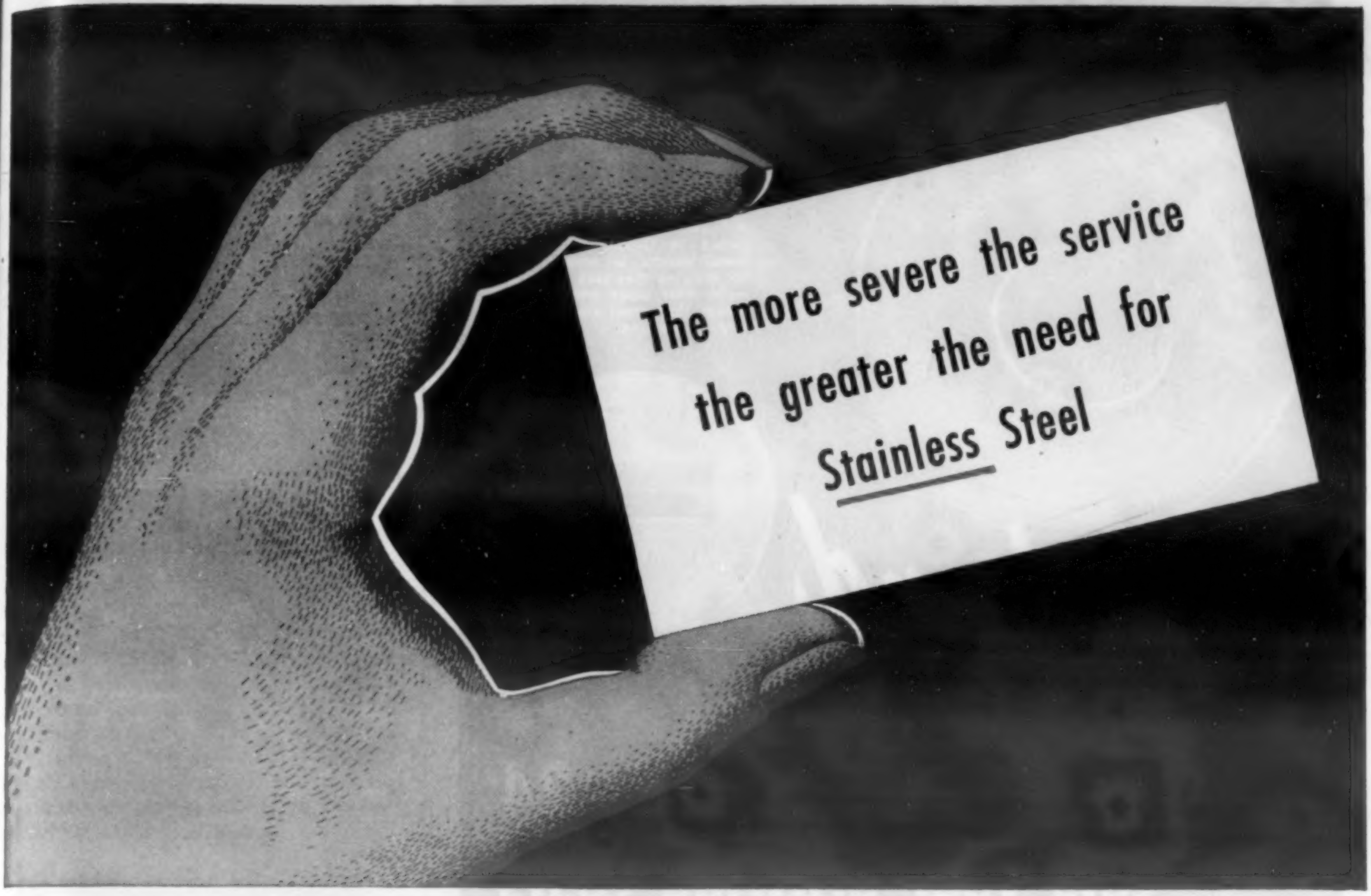
With the new interferometer, it is possible, for example, to check the flatness of both end surfaces of a gage block and at the same time determine whether the two surfaces are parallel to each other. The large model has a field view of 4¼-in. dia. while the smaller size has a 1⅞-in. capacity.

● *Sheldon Machine Co.*, 4258 N. Knox Ave., Chicago 41, have announced a new 10-in. bench lathe with a 1 1/16-in. hole through the spindle and an integral horizontal motor drive. It has the basic features of larger industrial lathes: ¾-in. collet capacity (1-in. collet capacity with nose type collet chuck), tapered roller spindle bearings, double walled worm feed apron with power cross feed, and full quick change gear box that gives a thread cutting range of from 4 to 224 threads per in.

Chemical Resistant Coating Can Be Applied Over Rust

A pigmented or non-pigmented liquid plastic coating which can be applied over old paint or tight rust to metal, wood and concrete surfaces by brush, spray or dipped methods is the development of the *Corrosite Corp.*, Chrysler Building, New York City. A prime coat is not used, and baking is not required. The coating, known as Corrosite, will air-dry, tact free, within 15 min.

The coating is a combination of thermoplastic and thermosetting resins, producing a non-oxidizing film which is said to be impervious to both acids and alkalis. It is also



If you want to reduce corrosion losses...

PASTE THIS IN YOUR HAT

MANUFACTURERS of high production industrial equipment will find in U·S·S Stainless Steel the answer to many of their toughest corrosion problems. And for three reasons:—(1) No other commercial metal can equal Stainless Steel in its high resistance to so many types of corrosives; (2) Stainless is unsurpassed for retaining high strength under high temperatures; and (3) Stainless Steel is available in such a wide range of analyses and in so many different forms—in plate, sheets, strip, wire, pipe and tubing, etc.—that it will meet almost any fabricating requirement and service condition.

Recent outstanding advances in the fields of engineering chemistry have been paralleled by equally important developments in the field of Stainless Steel. The versatility of this superior corrosion-resisting and heat-resisting steel has been constantly extended.

How ably the new and improved Stainless Steels meet today's stringent requirements is exemplified by the successful and extensive use of Stainless of various types in the electro-magnetic separation plant of the atomic bomb project at Oak Ridge. Here, where the materials problem is complicated by the complexity of the chemical processes carried on, Stainless Steel has been used to do an outstanding job, both in reducing equipment deterioration and in holding costly product losses to a minimum.

In U·S·S Stainless we offer a perfected, service-tested Stainless that is available in a wide variety of analyses, and in the most complete range of shapes, forms, and surface finishes anywhere obtainable. Our engineers are specialists in its application—they will be glad to work with you to insure its most efficient behaviour.

U·S·S STAINLESS STEEL

SHEETS · STRIP · PLATES · BARS · BILLETS · PIPE · TUBES · WIRE · SPECIAL SECTIONS

S-905

UNITED STATES STEEL AMERICAN STEEL & WIRE COMPANY, Cleveland, Chicago & New York
CARNEGIE-ILLINOIS STEEL CORPORATION, Pittsburgh & Chicago · COLUMBIA STEEL COMPANY, San Francisco
NATIONAL TUBE COMPANY, Pittsburgh · TENNESSEE COAL, IRON & RAILROAD COMPANY, Birmingham
UNITED STATES STEEL SUPPLY COMPANY, Warehouse Distributors—Coast to coast: UNITED STATES STEEL EXPORT COMPANY, New York

said to be more flexible than paint; non-inflammable, waterproof, non-contaminating, tasteless and odorless when dry. Two coats are usually used for lasting protection against generally experienced corrosive conditions, but up to three or four coats may be recommended for possible extreme acid or acid fume conditions.

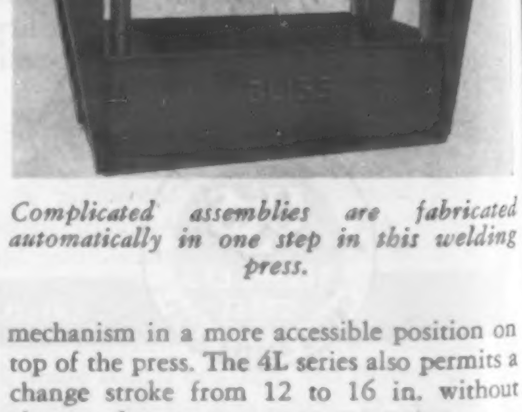
Maximum heat limitations are 265 F hot air temperatures and 140 F constant immersed liquid heat. Coverage up to 450 sq. ft. per gal. can be expected, and successive coats may be applied 1 hr. apart.

Welding Press for High-Speed Assembly

High-speed assembly of large metal section is possible on a welding press recently developed by the *E. W. Bliss Co.,* 450 Amsterdam Ave., Detroit 2. In operation, the units to be assembled are placed in position on the lower die or pre-loaded on conveyors, after which the press cycle is completed automatically. The lower die is raised until it contacts the upper die, which contains welding tips placed in positions corresponding to the spots to be welded on the metal section.

Limit switches stop the slide in the correct position, perform the welds, and return the slide to the lowered position when all the welds are completed. The spot welding is done electrically, and any number of welds can be made at once.

The new welding press is available in two models, which are essentially the same except for the position of the driving mechanism. For use in shops with limited headroom, the 4LU series is designed with the driving unit in the base. Where headroom is no object, the 4L series has the driving mechanism in a more accessible position on top of the press. The 4L series also permits a change stroke from 12 to 16 in. without change of parts.



Complicated assemblies are fabricated automatically in one step in this welding press.

In both series, the lower die moves up to contact the stationary upper die, and is supported at four points to assure accurate positioning.

New Resistance Welding Alloy for Seam Welding

A new seam welding electrode metal claimed to give improved life and reduced costs per weld is a result of development work by *P. R. Mallory & Co., Inc.*, Indianapolis 6, Ind. Known as Mallory 22 Metal, this material is a high conductivity copper base alloy containing cadmium and zirconium.

The high conductivity and hardness with its resistance to annealing makes the metal a suitable electrode for coated metals such as galvanized iron, terne plate, etc. and ordinary carbon steel.

Tester Designed for Small Section, Low Tensile Materials

The Amschler horizontal tensile testing machine, designed for testing materials of small section or low tensile strength such as fabrics, papers, yarn, leather, fine wires and particularly materials like rubber that have considerable elongation, has been put on sale by the firm of *Adolph I. Buehler*, 228 W. La Salle St., Chicago 1, Ill.

Desirable features incorporated in this small testing machine are: a pendulum load weighing system that guarantees accuracy; five load ranges that permit wide application; a convenient gripping mechanism; and an easily visible indicator and automatic load-extension diagram recorder.

The Amschler machine is operated by applying a stress that moves the pulling specimen holder away from the fixed specimen holder which is attached to the weighing, indicating and recording mechanism. To operate this tester, a motor drive mechanism that has eight speeds ranging from 0.1 to 20 in. per min. applies the stress. As the stress increases, the tensile load is balanced by the deviation of the pendulum from the vertical position. At the same time, the movement of the pendulum is indicated on a straight line scale. After fracture, the pointer remains at the point of maximum load. Finally, the elongation is read either from a scale at the side of the machine or from the record diagram that can be either full or double size.

Supersonic Waves Tests Welds for Defects

Welds in ferrous metals and light metals can be inspected for lack of bond, inclusions or voids by means of a newly developed testing technique employing supersonic sound waves. The testing method is an adaptation of the supersonic testing equipment, known as the Reflectoscope, which is produced by *Sperry Products, Inc.*, 1505 Willow Ave., Hoboken, N. J.

The new development is known as angle

The searching unit of the Reflectoscope, shown here, is aimed at the weld line and the pulsating sound beam is projected through the weld.

beam transmission and makes possible the entrance of the sound beam into the welded part at an angle. The searching unit, whose primary element is a quartz crystal, can be placed on the smooth parent metal adjacent to the weld, or even at some distance from it. The energy travels by successive reflections between the surfaces of the material until an interface is reached.

The weld metal itself will not constitute a reflecting interface, but any voids or inclusions will reflect part of the sound beam back to the searching unit, where it will be amplified to provide a vertical deflection of the horizontal trace or an oscilloscope screen. A time marking system allows accurate calibration to determine the distance from the searching unit to the flaw, and it is thus possible to distinguish between any defects in the plate and those in the weld area.

Since sound waves travel equally well in aluminum and magnesium as in ferrous metals, welds in light metal plate and sheet stock can also be inspected. Depth of penetration in these metals is comparable to that in steel, and defects of the same small size can be located if desirable.

Emulsion Cleaner Is Suitable for All Metals

A new development in emulsion cleaners that can be safely used on all metals and is especially desirable for cleaning buffed zinc-base die castings or aluminum parts has been announced by *Apothecaries Hall Co.,* Waterbury 88, Conn.

The cleaner has special surface active agents which impart to it a high degree of emulsifiability, wetting and penetrating action, and rapid rinsability. It is classed as a safety solvent with a flash point of 100 F. Operation is at room temperature. Ordinary steel tanks are used to hold the cleaner.

Tailored POWER PACKAGES *to fit your plant*

It's easy to start planning for a General Electric copper-oxide rectifier set-up with this new, helpful 28-page booklet. It gives all dimensions of rectifier units—shows just how compact each unit is—to help you squeeze more amperes into existing floor space. You'll want it for present planning—you'll want it for your files for future planning—because it actually tells you what you want to know about an economical, long-lived copper-oxide rectifier "package" for your plant.

COMPLETELY AUTOMATIC CONTROL—This booklet explains automatic "on load" control—the control system that puts tank-voltage control right at the tank. It shows you the operator's control box and the induction-type control that maintain voltage at ±2 per cent at all times—give instant finger-tip control of voltage at any time.

RECTIFIER "PACKAGES"—General Electric copper-oxide rectifier "packages"—complete rectifier systems for all standard amperage requirements—are clearly described. The famous G-E "2000" standard automatic "package," other packaged systems, and rectifier units are all explained in this handy booklet.

To get your copy of *Copper-oxide Rectifiers and Controls* early, fill out the coupon, and mail it today.

Section A10-652
General Electric Comany
Bridgeport 2, Connecticut

Please send me my free copy of Copper-oxide Rectifiers and Controls.

NAME ____________________

COMPANY ____________________ TITLE ____________

ADDRESS ____________________

CITY ____________ ZONE ______ STATE ____________

GENERAL ELECTRIC

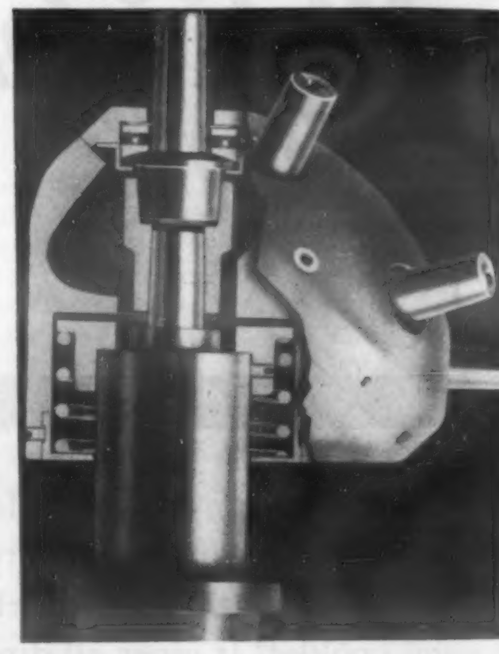
Drill Press Turret Is Self-Centering

An automatically aligning drill press turret has been released for sale by *Howe & Fant, Inc.*, Dept. 11S, South Norwalk, Conn. This turret is so constructed that its six spindles are automatically centered and aligned by the drill press spindle. The turret thus has a sustained accuracy equivalent to the drill press to which it is attached.

The six spindles are mounted on floating bearings so that they are free to move laterally and angularly as well as to rotate. As the tapered driving unit, attached to the drill press spindle, engages the mating taper of a spindle, it centers and aligns the spindle and locks it in that position until the drilling operation is completed.

This patented construction is said to overcome the fundamental difficulty of aligning with a live spindle which has heretofore prevented successful application of the turret principle to drilling machines.

Another feature is that drill turret has no gears, teeth, or projections to clash and wear. Driving power is transmitted directly from machine spindle to spindle by the same tapered surfaces that accomplish alignment.



Cutaway view of drill turret shows how automatic centering and alignment are accomplished.

The turret, called Lign-o-matic, is simple to attach and detach. Six different drilling operations may be performed, such as drilling, reaming, counterboring, etc., without the operator moving the work. Tool changes are made by raising the drill press lever and indexing the turret to another station.

● *D. C. Cooper Co.*, 1469 S. Michigan Ave., Chicago 5, Ill., have announced a new product, known as D. C. Aluminum Etch, for conditioning aluminum surfaces so that paint will adhere. This product is in liquid form, and is used cold, diluted with 50 parts water. The aluminum parts can be immersed in this solution from 5 to 30 sec., then rinsed, and the parts are ready for painting. The surface is etched slightly by this process, improving the bond for paints and lacquer.

Gas Generator Operates Automatically

The endothermic generator, produced by *Ipsen Industries, Inc.,* 311 Blackhawk Bldg., Rockford, Ill., is an automatic atmosphere producer which can supply one or more furnaces with equal economy.

This central station generator produces a gas that is protective to steels and makes possible clean and bright hardening in properly constructed furnaces. The addition of small amounts of certain gases into the generated gas produces a clean carburizing atmosphere. Adding small amounts of ammonia, the enriched gas becomes a gas cyaniding atmosphere. Properly constructed furnaces, however, are essential for proper application of the Ipsen generator gas.

In producing the gas, air and raw gas are drawn through flow meters, accurately proportioned and pumped through a fire check into the externally heated and catalytic cracking retort. Upon cooling the endothermic-processed gas can then be piped and metered to one or more furnaces. Once proportioning is set, the generator is completely automatic, generating only the volume of gas required.

Cupola Blocks Provide Flexible Joints

Refractory cupola blocks which permit the setting of a wide range of lining diameters with whole blocks of a single shape are now being produced by *Harbison-Walker Refractories Co.,* Pittsburgh. The range of diameters accommodated by the given shape is reported as from 2 ft. to 8 ft. and larger, inside diameter, in multiples of 3 in.

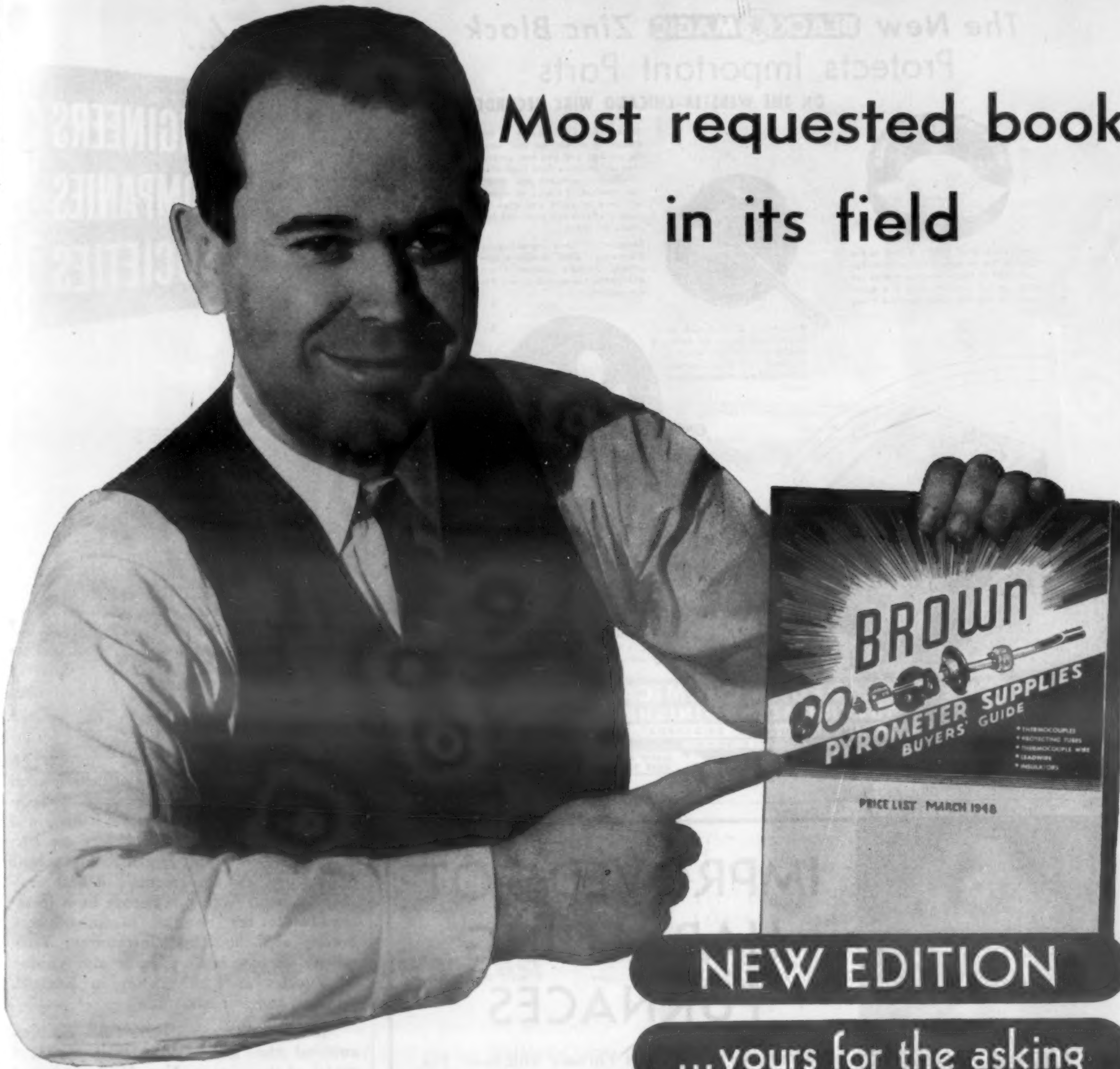
The new shape, known as the Universal

The convex and concave ends on these cupola blocks allow a flexible joint to be made.

Cupola Block, is of standard 9-in. by 6-in. by 4-in. dimensions and features alternate convex and concave ends which form a flexible but tight fitted-curve end joint that maintains a contact over the entire end surfaces regardless of the diameter of the lining. In this manner the various lining diameters can be set entirely of whole blocks without cutting.

The flexibility of the joint also permits accurate setting in stacks that are warped or slightly out of round. Because of the flexible joint, block is suggested for vertical tanks or furnace linings rather than horizontal cylindrical shells.

Most requested book in its field



NEW EDITION

...yours for the asking

If you have even one pyrometer instrument in your plant, you should have the *new edition* of this book. It's chock full of important data and ordering information in an easy-to-use tabular form. Who can tell — if a thermocouple should fail, you may urgently need this Buyers' Guide *today* to avoid costly shut-downs.

Many thousands of purchasing, engineering and maintenance men have acclaimed the old edition a boon to their work of specifying or ordering any pyrometer supply.

This *new edition* is even better. Send for your free copy right now.

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Sure, without obligation send me the new edition of the Brown Pyrometer Supplies Buyers' Guide No. 100-2.

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BROWN *Advanced Instrumentation* FOR BETTER PROCESSING

Product of Minneapolis Honeywell

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Engineers

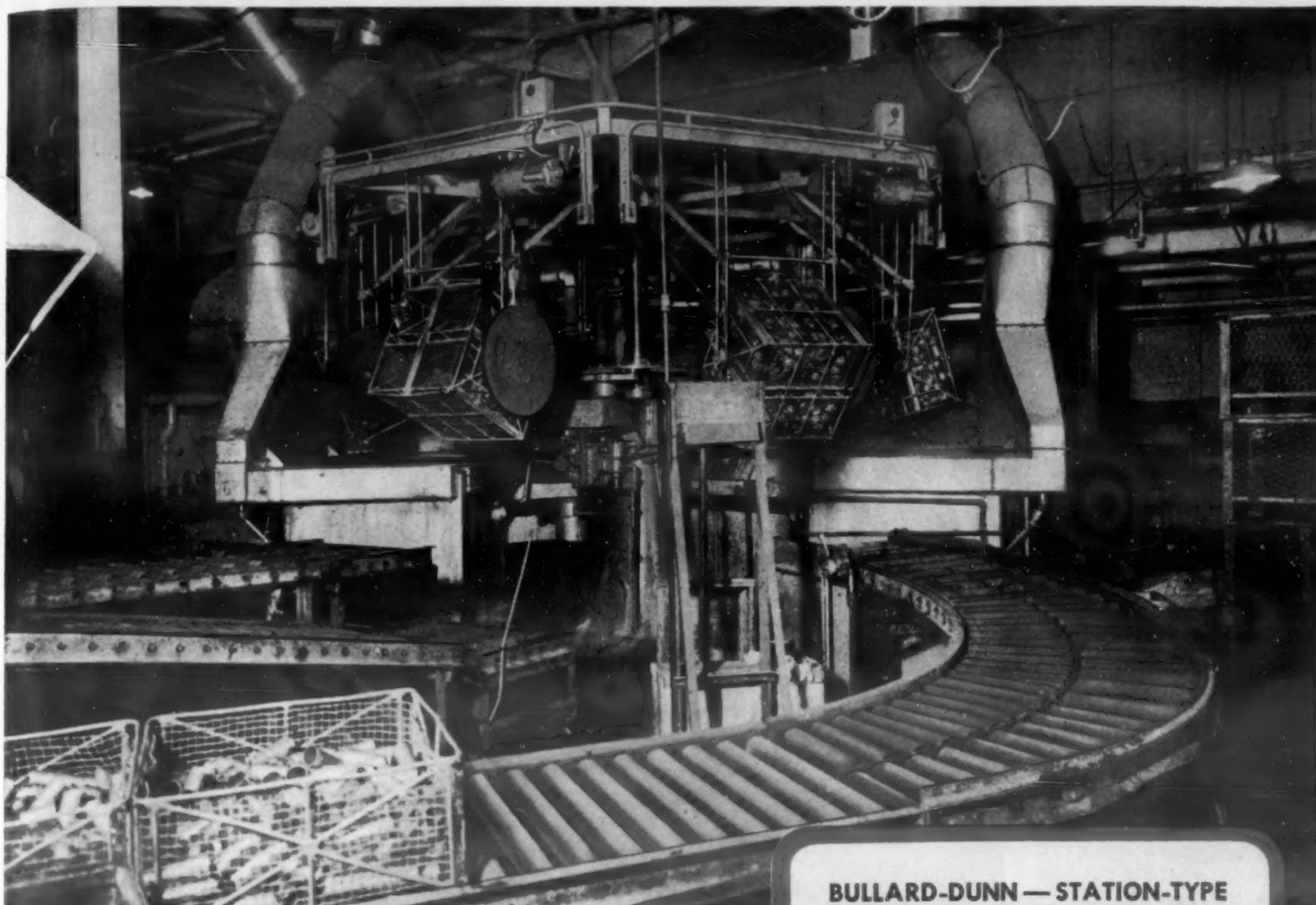
Melvin Williamson, an experienced aluminum rod and bar production man, will supervise the operation of the Kaiser aluminum rod and bar mill to be installed at the company's Trentwood Rolling Mill near Spokane, Wash. For the past five years he has operated the rod and bar mill at Shawinigan Falls, Quebec. At the Trentwood mill several revolutionary principles of design will make it the world's most modern and flexible mill of its kind. A native of Canada, Mr. Williamson was graduated from Queens University at Kingston, Ont., and later was employed by the Aluminum Co. of Canada at their Kingston Works.

Dr. *Robert F. Mehl*, head of metallurgical engineering at Carnegie Institute of Technology, delivered the Hatfield Memorial lecture in London, May 5, before the Iron & Steel Institute of England, his subject having been on fundamentals of heat treatment of steel. While in Europe he is speaking before the Swedish Metallographers' Society and the Royal Institute of Technology in Stockholm. He is also visiting laboratories and universities in England, Scotland and Sweden.

Marvin J. Udy, of Niagara Falls, has been awarded the 1948 Jacob F. Schoellkopf medal of the western New York section of the American Chemical Society for his contributions to the refining and utilization of chromium. A consultant in chemistry and metallurgy, he developed a process for treating low-grade chrome ores, such as found in the United States, thus making them commercial. He has also devised new methods for plating with chromium and cadmium.

W. H. Rowand has been named chief engineer, Babcock & Wilcox Co. The position is a new one, created by the recent promotion of *Alfred Iddles* to the presidency of the company. He has been with the company for 19 years, has served in many engineering capacities, and been active in the design and development of boilers. He is the author of several technical papers and prominent with the American Society of Mechanical Engineers.

Wayne H. Gunselman has been made general manager of the new nonferrous division of the Buffalo Pipe & Foundry Corp. Previously he was director of research and foundry engineer with the Samuel Green-



Automatic Station-Type Conveyors

SPEED UP

Treatments at Lower Cost

Whatever your sequence of treatments, you can accurately time it and do better work at lower cost with a Bullard-Dunn Station-Type Conveyor, engineered to your specifications.

TESTED ON ALL KINDS OF WORK

During the past ten years, these fully automatic Bullard-Dunn conveyors with built-in hydraulic systems, have piled up great performance records on a wide variety of processes. Bullard-Dunn Process descaling is just one. Others include: pickling, bright dipping, plating, blackening, heat treating, hot tinning, rubber-mould cleaning, phosphate coating, treating aluminum and zinc.

WORK HOLDERS TO FIT THE JOB

Rotating barrels and cages for small parts and racks for large parts are available that can be used for both acid and alkali solutions and for high temperature salt bath treatments. Special work holders will be designed as required.

For details about Bullard-Dunn Station-Type Conveyors, write for Bulletin MM-BD-45. THE BULLARD COMPANY, Bullard-Dunn Process Division, Bridgeport 2, Conn.

BULLARD-DUNN — STATION-TYPE CONVEYOR AT WORK . . .

. . . conveying annealed brass cups through 4-step pickling sequence between drawing operations at Bridgeport Brass Company, Bridgeport, Conn. *Operation:* baskets, arriving from furnace on roller conveyors, are loaded into specially designed, stainless steel cages, permanently fixed to machine . . . two baskets per cage. Cages rotate throughout accurately timed sequence in solution and while machine is automatically rising, indexing, and lowering. *Production:* Faster, better, more economical than previous hoist-operated unit. *Maintenance:* Machine has been operating for over one year without shutdown for major repairs.

BULLARD

Bullard-Dunn Descales Without Dimensional Change

The Bullard-Dunn Process removes scale and oxide from ferrous metallic surfaces without attacking the work. Fast . . . thorough . . . economical . . . simple to operate. Investigate. Bulletin MM-BD-46 tells story.

News of...

ENGINEERS
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field Co., Inc. Prior to that he was director, Metallurgical Dept., National Bronze & Aluminum Foundry Co., Cleveland. The newly-created Nonferrous Div., Buffalo Pipe & Foundry Corp., will specialize in the production of permanent mold aluminum, brass and bronze castings. The corporation has acquired the assets of the American Sigma Corp., Buffalo.

G. E. Stoltz has been appointed consulting metal working engineer and *W. R. Harris* manager of the metal working section, both of the Industry Engineering Dept., Westinghouse Electric Corp. Mr. Stoltz joined Westinghouse in 1909, immediately after graduation from Ohio State University. He has been continuously identified with steel mill activities since then. Mr. Harris joined Westinghouse in 1937 and entered the Industry Engineering Dept. the next year.

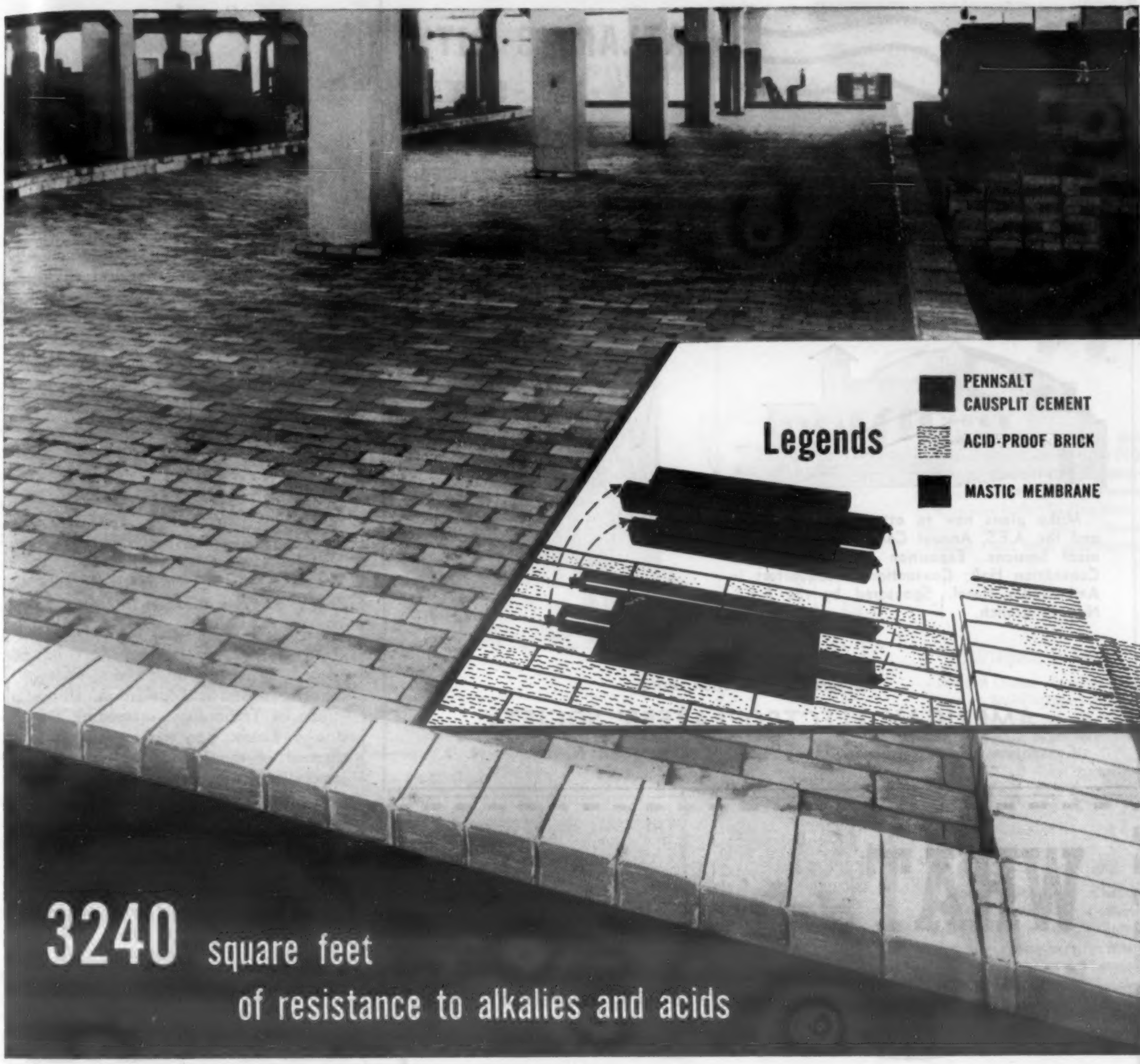
Frank R. Palmer, former vice president in charge of sales, has been elected president of the Carpenter Steel Co. to succeed *J. Heber Parker,* who becomes chairman of the board. Mr. Palmer joined Carpenter Steel 31 years ago as foreman of the electric furnace melting department. From 1918 to 1928 he was a member of the metallurgical department. Later he did advertising and sales development. He is author of the textbook, "Tool Steel Simplified," and other publications. Mr. Parker has been with the company 45 years, starting in the chemical laboratory, then being in the crucible department. He was advanced to assistant superintendent, became chief metallurgist and served as vice president from 1916 to 1941.

H. O. Amble has been placed in charge of tool and die control, a new division of American Car & Foundry Co., making his headquarters at the Berwick plant. Born in Norway and educated in European schools, he went to Buffalo in 1910. He has served in various plants as shop engineer and tool and die estimator, while during the war he was in charge of ordnance engineering at Berwick, engaged in manufacturing armor plate, combat tanks and bulldozers.

Raymond K. McClintock, who has received the award for exceptional service from the Navy Bureau of Ordnance for development of the proximity fuze, has been made assistant to the chief engineer, Radio Tube Div., Sylvania Electric Products, Inc. He has been granted several patents in the radio tube field.

Omar V. Greene, who joined the Carpenter Steel Co. in 1928 as a staff metallurgist, was recently promoted from assistant general sales manager to manager of product development.

Neil F. Ritchey has been made an engineer in the Technical Service Dept., Reynolds Metals Co., Louisville 1. For the



How APPLETON ELECTRIC used Pennsalt Causplit* Cement to help protect a new floor

*REG. U. S. PAT. OFF.

Appleton Electric Company, leading producer of electrical equipment, recently added this 120′ x 27′ pickling room floor to its Chicago plant facilities. Designed to handle spillage and discharge from alkaline cleaning tanks and sulfuric acid pickle tanks, it is an outstanding example of custom built, corrosion-resistant flooring.

The concrete base is pitched toward 6 drains, and surrounded by a 12″ concrete coping. The exploded view above shows how the acid-proof brick was buttered on *5 sides* with Pennsalt Causplit Cement —providing a corrosion-resistant sheathing on top of the two-coat mastic membrane.

Causplit Cement is one of Pennsalt's synthetic resin cements designed for use as a mortar or pointing material for acid-proof brick or tile. It can be used where conditions are alternately alkaline and acid . . . may hold the answer to an immediate problem of yours. For further details, write Special Chemicals Division, Pennsylvania Salt Manufacturing Company, Philadelphia 7, Pa.

PENN SALT

Corrosion-resistant Cements of many types for Acids, Alkalies, Solvents

News of...
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past several years he has been with the General Electric Co. at Fort Wayne, Ind., where he was a metallurgical engineer in charge of nonferrous metallurgy in the laboratory. He has written for technical publications.

Paul Kates has been made factory superintendent of the Ferro Enamel Corp., having been active in the porcelain enameling industry for many years. He is a graduate in ceramic engineering of Ohio State University.

Charles F. Hanks, Jr. recently joined the research department of Harbison-Walker Refractories Co., Pittsburgh, having formerly been with the research laboratory of the Westinghouse Electric Corp. at East Pittsburgh. He is a graduate in ceramics of the University of Illinois.

Dr. *Christopher E. Barthel, Jr.* has been named chairman of physics research at Armour Research Foundation, Illinois Institute of Technology, succeeding Dr. *Haldon A. Leedy,* who was recently appointed director of the foundation. He has been supervising the activities of light and optics, X-ray diffraction and spectroscopy sections of physics research. He has been presented the Navy's Distinguished Civilian Service Award for outstanding contribution to the war effort.

Charles S. Redding recently observed his 40th anniversary with Leeds & Northrup Co., maker of electrical measuring instruments, automatic controls and heat treating furnaces. He has been president of the company since 1939. Among positions with the company he has held have been factory manager and vice president in charge of engineering and development. He has been unusually prominent in civic and technical affairs of Philadelphia, as well as national technical societies.

Companies

More than $596,602,000 will have been invested since the war in new plants and equipment in Pennsylvania by 417 metal and metal product companies, including 26 basic iron and steel product companies, according to a State survey. This is part of an expansion of over $2,000,000,000 reported by 1086 companies. The largest expenditures by groups, in order named, were by steel companies, makers of electrical machinery, apparatus and parts, and by companies making machinery and parts.

Twenty-three of the nation's leading iron

News of...

ENGINEERS COMPANIES SOCIETIES

and steel makers with extensive mining interests have been urged by New York state officials to investigate two new deposits of iron ore explored recently in the Adirondacks. They claim that a ton of iron ore from the Adirondacks costs, upon arrival at Pittsburgh, the same as a ton from the Minnesota Mesabi range, but New York's ore is of much higher grade. The half-billion-ton iron reserve in the northern Adirondacks is a secondary iron reserve. The ore is chiefly magnetite which, in pure form, is 68% iron as against 45 to 50% at Mesabi. In New York, the ore is a year-round transportation possibility.

The first atomic energy show of its kind was held in early May at Miamisburg, Ohio, under sponsorship of *Monsanto Chemical Co., U. S. Atomic Energy Commission* and *Miamisburg Community Civic Assn.* Much of the "live" show was produced in an atmosphere of "black light" (ultraviolet), with the auditorium in total darkness, through use of specially prepared fluorescent devices and materials. One device was a "ping pong pile," or a machine 6-ft. square, containing 126 electrical switches, more than 2900 other parts, the 150 ping pong balls demonstrating chain reaction. Another device, requiring ultraviolet light, showed construction and actual action of an atom and its component parts. Fission was illustrated by a large "neutron gun", with effects audible and visible.

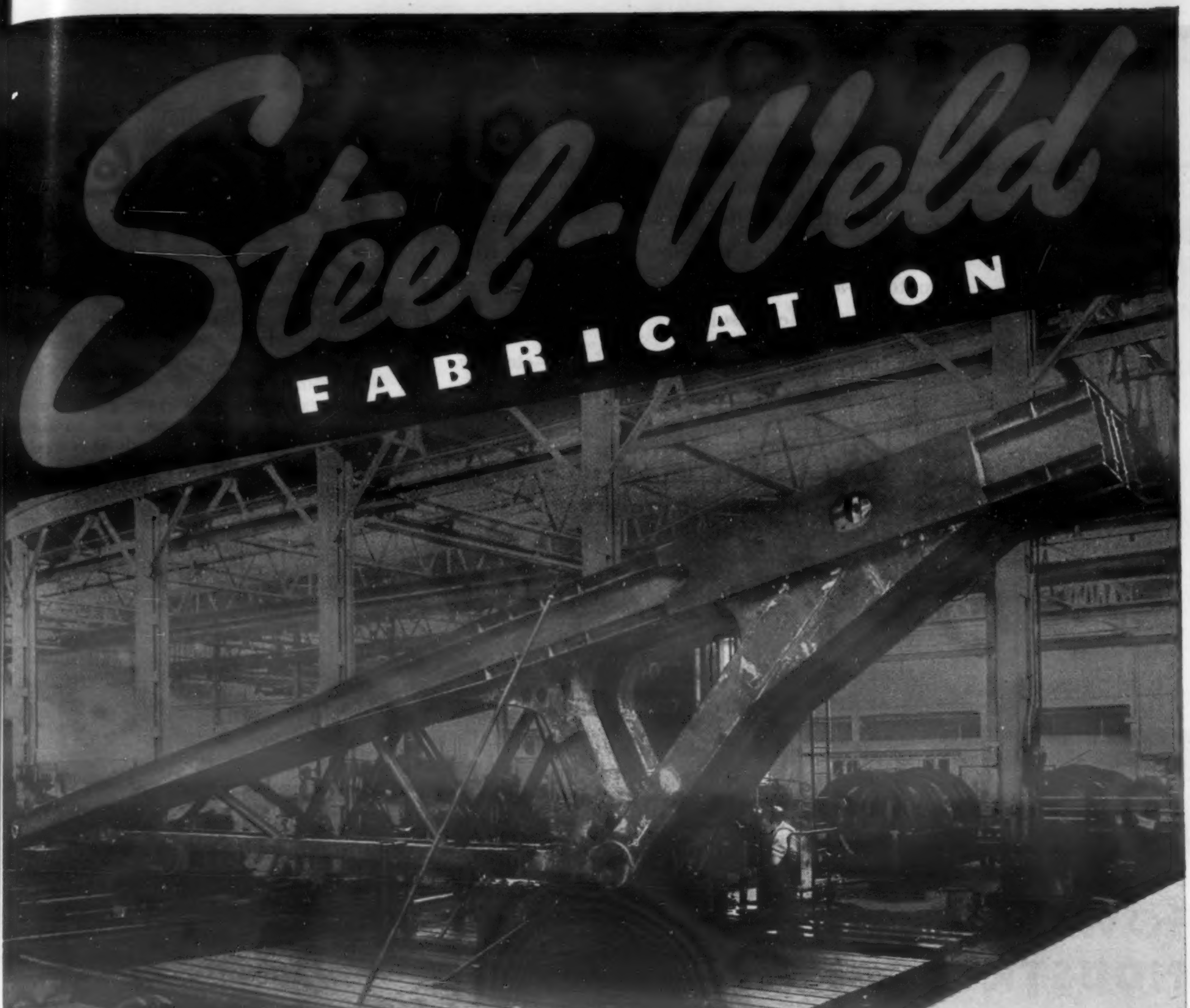
The name of the *Mathieson Alkali Works (Inc.)* has been changed to *Mathieson Chemical Corp.* to indicate more clearly the field and scope of its activities.

The huge basic magnesium plant at Henderson, Nev., has been sold by the War Assets Administration to the state of Nevada for $24,000,000, the plant having originally cost $140,000,000. During the war it was operated as the largest magnesium metal plant in the world.

The first aluminum foil plant in Mexico, erected by *Reynolds Internacional de Mexico, S.A.* at a cost of $2,500,000, was dedicated April 19. Located in a suburb of Mexico City, it is now turning out foil, but for the future is planned rolling of aluminum sheet and fabrication of aluminum shapes.

The newly-formed *Morton-Gregory Corp. of Michigan* has bought the manufacturing assets and patent interests of the Nelson Stud Welding Corp. of Lorain, Ohio, and its associated companies. Executive and sales offices have been established in the Manhattan Bldg., Toledo, Ohio. The new purchasing company was formed by Detroit and Toledo inventors, engineers and businessmen who are primarily interested in the electrical specialty fields. Henry J.

(Continued on page 156)


Steel-Weld
FABRICATION
In the illustration above you see the two main gantry supports of the mammoth Marion Strip Mining Shovel being machined in the Mahon machine shop. Each support is 58 ft. long and weighs 16 tons . . . further evidence of Mahon's ability to meet your welded steel requirements regardless of design, size or weight. A staff of Steel-Weld design engineering experts, backed by highly skilled craftsmen, are your assurance of every advantage of Steel-Weld Fabrication.
THE R. C. MAHON COMPANY
Detroit 11, Michigan
Engineers and Fabricators of Welded Steel Machine Bases and Frames, and Many Other Welded Steel Products
MAHON

News of... ENGINEERS COMPANIES SOCIETIES

Morton, Detroit, is president and George E. Gregory, Toledo, vice president and general manager. Stud welding was invented and developed eight years ago by Ted Wilson while working as a $11 per day welder in the Mare Island Navy Yard. Nelson started in his own garage with revolutionary flux-filled studs and an automatic welding gun by which they could be end-welded to ship plate and other metal surfaces.

E. I. du Pont de Nemours & Co., Inc. will begin immediately on a $30,000,000 expansion of research facilities at its Wilmington, Del., experimental station, the largest single laboratory project the company has ever undertaken. It will include ten new laboratory and semi-works buildings for long-range research and development of new chemical discoveries. Du Pont research projects in other cities will be moved to the new Wilmington center.

The *Loftus Engineering Corp.*, 610 Smithfield St., Pittsburgh, has consolidated its manufacture of heat treating furnaces into a newly formed heat treating division directed by George C. McCormick.

The *Babcock & Wilcox Co.* has completed a special building, with concrete walls 9- to 40-in. thick, to house its 2,000,000-volt X-ray machine to examine welds in high pressure, high temperature boiler drums made at its Barberton, Ohio, works. With the new machine much shorter exposure time is required in X-raying pressure vessels, 4½ to 6½ in. thick. Laminations which have not been seen heretofore on radiographs of heavy plate are more easily found and a sensitivity to variations under 2% of the weld thickness is obtained. Exposure time for 5½-in. plate is 6 min. when using a film distance of 6 ft. The company originated this testing in 1929 when a medical X-ray machine was adapted.

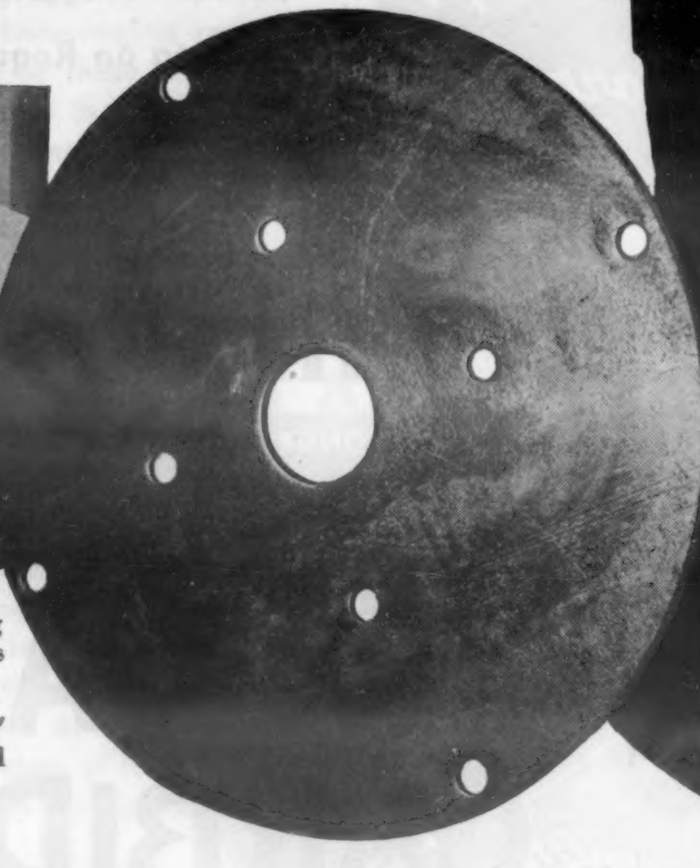
A 5-min. sound motion picture film, "The World's Fastest Steel Rolling Mill," describes the new 5-stand tandem mill at the Aliquippa Works, Pa., of the *Jones & Laughlin Steel Corp.* The product of the mill is for the manufacture of tin cans, bottle caps, etc.

To assist the designer and engineer to use arc welded steel in the design of all types of machinery, the *Lincoln Electric Co.* has released a new movie, "Designing Machinery for Arc Welding." This 16-mm. sound color movie presents functional approach to design, its theme being to use the right material in right amount at only the right places.

The *Shenango-Penn Mold Co.*, Dover, Ohio, one of the country's first producers of ferrous and nonferrous centrifugal castings, is now a manufacturer of Meehanite metal castings, thus claiming combined good

These steel plate shapes

PUT PRODUCTION 9 STEPS AHEAD



(*Above*) No blanking, machining, drilling and reaming operations on these flywheels for By-Products Steel's customer.

(*Right*) Lukens steel plate flywheel, 2'7½" O.D. by ⅝" thick, with vanes and chopping knives attached, installed in a Dellinger ensilage cutter.

These flywheels are flame-cut, gang punched and flattened when shipped by By-Products Steel Co. Thus, Dellinger Manufacturing Company of Lancaster, Pa., avoids the nine operations formerly required in their plant to get these parts to the same degree of completion. Labor, machines and floor space are released for other work.

The scrap trimmed from these circles goes right back to Lukens open hearths to speed the making of more steel. Scrap allowance is made at the mill where its value is highest. The customer has no freight or handling charges on that scrap. He saves time and money.

Made from Lukens Steel Plate, these flywheels are uniformly high in strength, dependable and safe.

Prompt delivery is another advantage of buying your steel plate already shaped by By-Products Steel Co. We have more than 150 major machines for production of parts to be flame-cut, sheared, pressed, bent, blanked or shaped in any manner, using carbon, alloy and clad steels.

Bulletin 270 pictures typical products made by By-Products Steel Co., Division of Lukens Steel Company, 419 Strode Avenue, Coatesville, Pennsylvania.

LUKENS BY-PRODUCTS STEEL DIVISION

BY-PRODUCTS STEEL CO.

STEEL PLATE SHAPES

FLAME-CUT ★ SHEARED ★ PRESSED ★ BENT ★ BLANKED ★ WELDED

• • SPEED SCRAP TO THE MILLS TO MAKE MORE STEEL • •

News of...

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qualities from both centrifugal action and inherent characteristics of Meehanite. It claims that it is perhaps one of two in the country equipped to cast Meehanite centrifugally. The company has developed methods that permit casting virtually any symmetrical or annular shape, regardless of outer surface contour.

The *Linde Air Products Co.* will install a large, low-purity oxygen plant at the Steubenville, Ohio, steel mill of the *Wheeling Steel Corp.* It will produce 135 tons of oxygen daily, mostly for use in open-hearth furnaces.

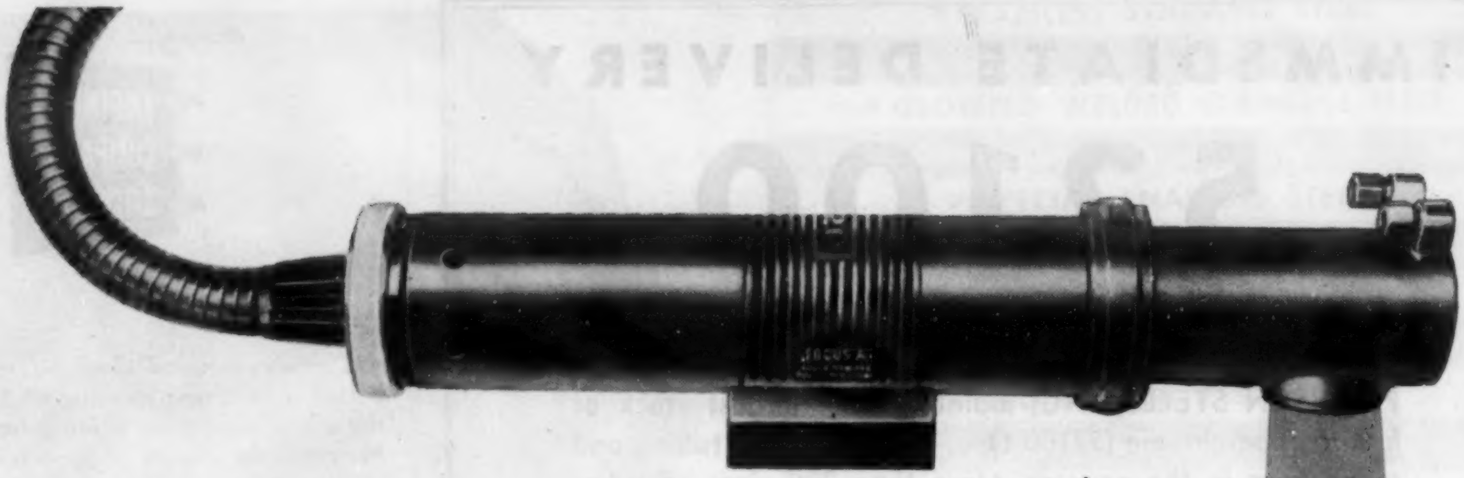
Lindberg Engineering Co., Chicago, maker of industrial heat treating and melting furnaces, has acquired the assets of the Electronics Div., Illinois Tool Works, that city, where it will continue manufacture of high frequency induction and dielectric heating equipment.

The plant in Riverside, Calif., recently acquired by *Revere Copper & Brass, Inc.* for the manufacture of copper-clad stainless steel cooking utensils, will be operated by a new unit of the company, to be known as Riverside Manufacturing Div. It will be in charge of J. M. Kennedy, vice-president of Revere.

Societies

The first *International Powder Metallurgy Conference* will be held at Graz, Austria, from July 12 to 16. Fifty papers have already been received from European countries, and American participation is cordially invited. Further information can be obtained from Prof. Gregory Comstock, Stevens Institute of Technology, Powder Metallurgy Laboratory, Hoboken, N. J., who is in charge of the American delegation.

The rubber division of the *American Chemical Society* awarded the first Charles Goodyear medal to Dr. George Oenslager, retired research chemist of the B. F. Goodrich Co., for his contributions to rubber chemistry, his principal achievement having been the discovery and use of organic accelerators in rubber vulcanization. This has been rated as second in importance in rubber technology to the discovery of vulcanization itself. It greatly reduces the time interval, improves quality, and allows use of several types of rubber which had previously been believed unsuitable. Dr. Oenslager also pioneered the increased use of carbon black in rubber which increased mileage life of tires. He performed chemical research on rubber for 34 years.

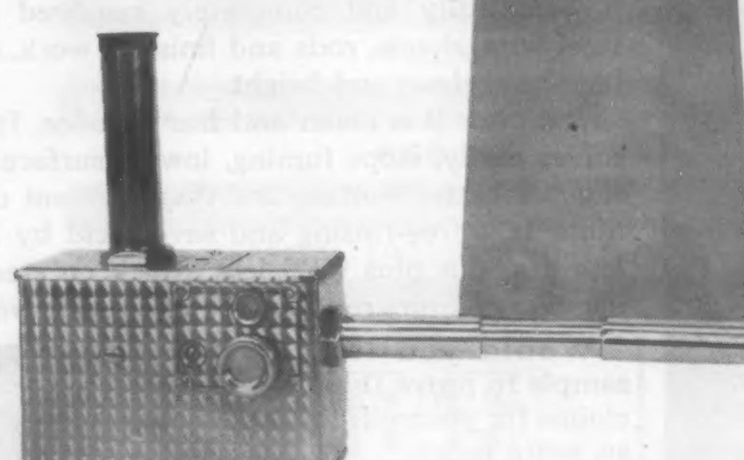


● **Scientists were given a new and valuable tool when Machlett introduced the AEG-50 beryllium-window X-ray tube. This potent source of high intensity, long wavelength X-radiation has already found many applications in research, medicine and in industry. Encouraging reports have been received on the efficacy of these X-rays in therapy, sterilization, and genetic studies. In the industrial field, the tube has found unique use in continuous gauging of metal foil in rolling mills, in inspection of welds in thin sheet, and in a number of metallurgical applications.**

Measuring AEG-50 Output!

The very special nature and large amount of radiation from the AEG-50 introduced difficulties in measuring its radiation output. Investigators and engineers engaged in determining new applications for this tube have frequently asked for assistance with this measurement problem. In this connection it is gratifying to report that the Victoreen Instrument Company of Cleveland, Ohio, has now made available for use with the well-known Victoreen "r-meter" a special thin-walled thimble chamber which will give accurate results in terms of roentgens in the measurement of radiation of the quality delivered by the AEG-50.

Now, with this new measurement tool available, research and application engineers will find a still broader field of utility for the AEG-50 beryllium-window X-ray tube.



MACHLETT

X RAY TUBES SINCE 1897
TODAY THEIR LARGEST MAKER

MACHLETT LABORATORIES, INC.
Springdale, Connecticut

News of...

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The *Resistance Welder Mfgrs. Assn.* reported at a recent meeting at Detroit that the use of resistance welding has grown to five times the volume of pre-war. Deliveries of equipment in 1947 were double those for 1942.

The *Electric Metal Makers Guild, Inc.* will hold its sixteenth annual meeting at Bethlehem, Pa. June 16-18. Among the papers to be delivered are: "Fundamentals in Steel Melting," by Dr. C. H. Herty, Jr., Bethlehem Steel Co., and "Hydrogen and Nitrogen Contents of Steel" by C. E. Sims, Battelle Memorial Institute. The annual banquet will be addressed by J. M. Sylvester, general manager, Bethlehem plants.

The *National Screw Machine Products Assn.*, 13210 Shaker Square, Cleveland 20, announces two scholarships, each valued at $1500, the first ever to be offered in connection with the screw machine products industry and its engineering techniques. The scholarship involves a 3-year cooperative course in screw machine engineering at Rochester Institute of Technology from September, 1948 to June, 1951. Donors are the Titan Metal Mfg. Co., Bellefonte, Pa., and the D. A. Stuart Oil Co., Chicago. Each scholarship amounts to $500 per year for the 3-year course.

Employees of the Atomic Energy Commission at the Hanford works now have the opportunity to engage in college work at the University of Washington, Washington State College, University of Oregon, Oregon State College and the University of Idaho, all of which have agreed to grant credits toward degrees for work done at Hanford. The plan was devised by General Electric Co., which operates the plant. Laboratory research work in nuclear fission and class room studies on off-work hours are provided for. The program of post-graduate study is called the "Graduate School of Nuclear Engineering."

The *Pressed Metal Institute* has elected the following officers: President, Tom J. Smith, Jr.; executive vice president, Walter A. Gorrell, E. J. McAleer & Co., Philadelphia; secretary-treasurer, J. J. Boehm, Boehm Pressed Steel Co., Cleveland.

A symposium emphasizing the supplementary relationship between electron and light microscopy sponsored by *Armour Research Foundation* of Illinois Institute of Technology and the Physics Dept. of the Institute is being held at the Stevens Hotel, Chicago, June 10-12. Technical papers will deal with the applications of electron and light microscopy to metals, biology, fibers, fine particles, fats and soaps, plastics, etc.; also with phase microscopy, microtomy, shadow casting and replica methods.

The technical committee of the *Gray Iron Founders' Society* has approved the

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Yes, you can select your exact requirements — by class or type steel tubing in almost any size — from Globe Steel Tubes Company.

What's more, you can be absolutely sure of getting a product in exact conformity with your requirements. That's because Globe Steel Tubes Co., meeting your needs, applies all the manufacturing and engineering "know-how", gained by exclusive specialization for nearly forty years in the production of steel tubing.

Equally important, you get the benefit of the most advanced volume production methods and rigid controls. To maintain the exact uniformity and high quality, constant chemical and physical checks and tests are conducted by Globe Steel Tubes Co.'s own completely equipped laboratories.

If you have a problem involving steel tubes—*stainless, mechanical* or *pressure* —consult Globe Steel Tubes Co. Globe engineers will give you the benefit of their specialized knowledge in a wide range of services and applications . . . to help make your product better . . . to increase your production . . . to lower your costs. GLOBE STEEL TUBES CO., Milwaukee 4, Wisconsin.

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preparation of a handbook on gray iron products, consultation service to members on technical and operating problems handled by correspondence, and a review of standard specifications on gray iron. The Society will also issue a "Cost Manual No. 2," describing its basic cost accounting system for foundries. The society has adopted a new emblem, featuring a cupola and receiving ladle, it being deep-etched and finished in two tones of silver, mounted on walnut.

A first prize of $750 and other prizes ranging from $200 to $500 will be awarded by the *Resistance Welder Mfgrs.' Assn.* for the best papers dealing with resistance welding subjects submitted to the American Welding Society, 33 W. 39th St., New York, before July 31, 1948. There are no restrictions as to the scope of the subject matter, providing it deals specifically with resistance welding. Minimum length requirement is 2500 words.

A school of engineering practice for graduate training in the engineering aspects of atomic energy is being established by the *Massachusetts Institute of Technology* for its own engineering students in the production plants of the Atomic Energy Commission at Oak Ridge, Tenn. Plans for the school have been sponsored jointly by the Commission and Carbide & Carbon Chemicals Corp. Students will live as a group in a dormitory at Oak Ridge, the school term being five months. Admission is restricted to graduate students who have been in residence at M.I.T. at least one term.

The *Industrial Diamond Assn. of America, Inc.* offers prizes of $100 and $50 to operators and other shop personnel for a best letter of suggestions on the theme: "Production and Economy Through Industrial Diamonds." The letter is not restricted as to content, style or length. Judges will be the Toolmakers and Research Committees of I.D.A. and prominent industrial engineers. Interested parties may contact Athos D. Leveridge, 501 Lexington Ave., New York 17, N. Y.

Irwin F. Holland, Pratt & Whitney, Hartford, Conn., has been named president, *American Society of Tool Engineers.* Other officers are: R. B. Douglas, first vice president; H. L. Tigges, second vice president; V. H. Ericson, third vice president; George A. Goodwin, treasurer; and W. B. McClellan, secretary.

The Low-Pressure Industries Div., *Society of the Plastics Industry,* will hold an industry-wide seminar on June 29-30 at the Statler Hotel, Washington. The purpose is to facilitate a better understanding between industry and government on latest developments, techniques and future requirements. Producers of vinyl film and sheeting met recently at New York to assure better and more uniform performance of products

Everything you want
IN A SINGLE PACKAGE

... install the *Bryant Industrial*

Pow·r·sembly

... the pre-engineered gas-combustion package!

Here is the answer to the problem of firing many types of air heaters, ovens, kilns, boilers and other industrial appliances.

The Bryant *Pow-r-sembly* is supplied in various arrangements of accessories to provide completely automatic, semiautomatic or manual operation. Furnished either as single or twin-nozzle units with one blower and governor.

The *Pow-r-sembly* can be adjusted for any type of flame. And, once set by a simple, quick adjustment, it will maintain the same flame characteristics day after day. The *Pow-r-sembly* is smooth-running and quiet in operation, burns any low-pressure gas. Flanged connections permit arrangement in any desired position... without special adapters or extra equipment.

Pow-r-sembly features the industry's most compact proportional mixer—the *Mixjector*. For prices, complete details and specifications, write Industrial Division, Bryant Heater Co., 1020 London Road, Cleveland 10, Ohio.

INDUSTRIAL DIVISION

GAS COMBUSTION FOR INDUSTRY

Bryant Heater Company

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made from these materials through development of quality standards. The group set up subdivisions covering six main end-use classifications.

The *National Assn. of Corrosion Engineers* has elected as president F. L. La Que, in charge of the corrosion engineering section, Development & Research Div., International Nickel Co., Inc. Other newly elected officers were: H. H. Anderson, vice president; O. C. Mudd, treasurer; and the following for a three-year term: L. J. Gorman, director representing active members; D. E. Stearns, director representing associate members; and Vance N. Jenkins, director representing corporate members. A. B. Campbell continues as the Association's executive secretary.

Meetings and Expositions

AMERICAN SOCIETY FOR ENGINEERING EDUCATION, annual meeting. Austin, Tex. June 14-18, 1948.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Applied Mechanics Div. meeting. Chicago, Ill. June 17-19, 1948.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, summer general meeting. Mexico City, Mexico. June 21-25, 1948.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting. Detroit, Mich. June 21-25, 1948.

INTERNATIONAL INDUSTRIAL EXPOSITION, Atlantic City, N. J. June 26-Sept. 11, 1948.

AMERICAN ELECTROPLATERS' SOCIETY, annual convention. Atlantic City, N. J. June 28-July 1, 1948.

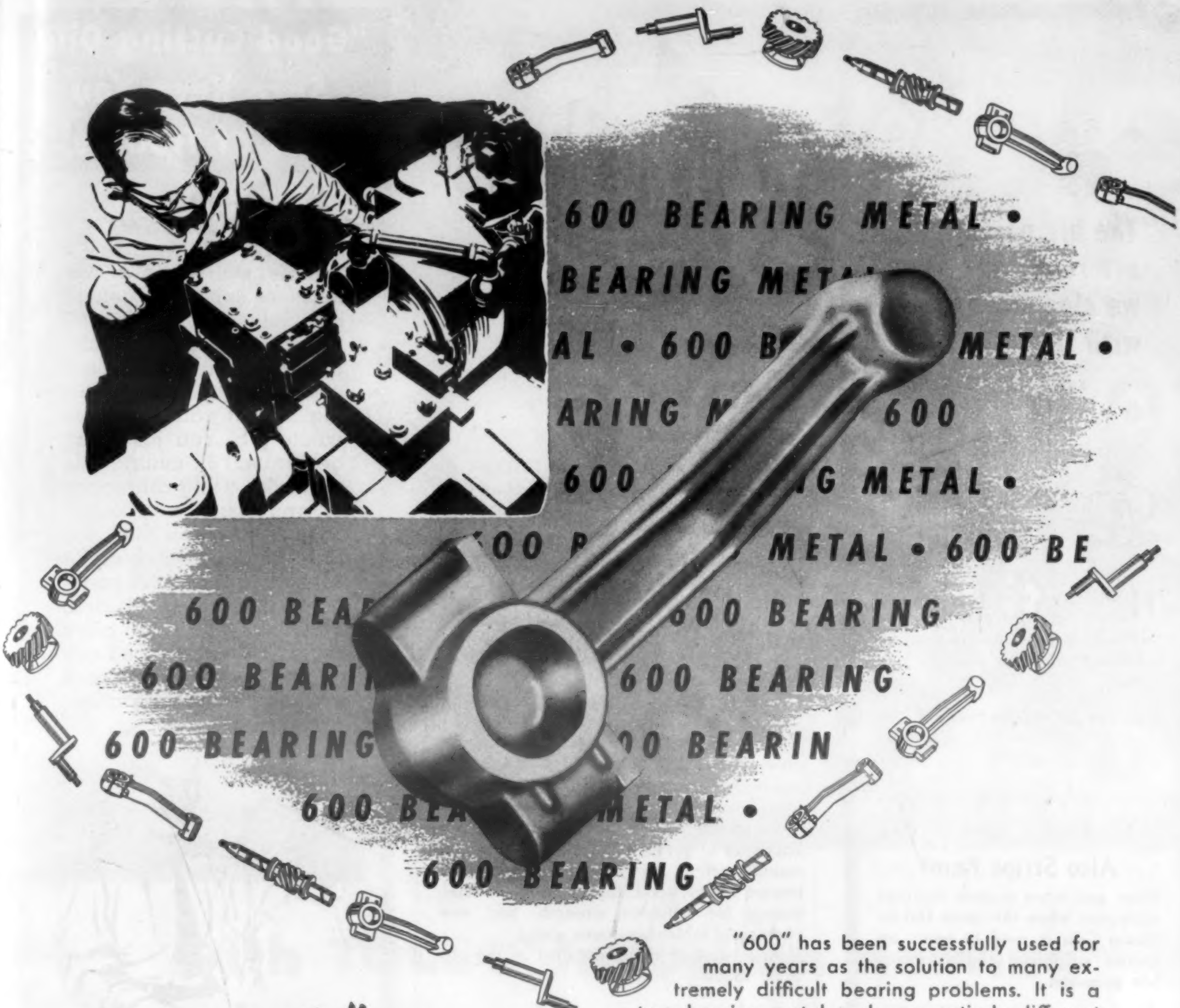
INSTITUTE OF THE AERONAUTICAL SCIENCES, summer meeting. Los Angeles, Calif. July 14-16, 1948.

AMERICAN SOCIETY OF CHEMICAL ENGINEERS, summer convention. Seattle, Wash. July 21-23, 1948.

WESTERN PACKAGING EXPOSITION, Packaging, packing and shipping conference. San Francisco, Calif. Aug. 10-13, 1948.

SOCIETY OF AUTOMOTIVE ENGINEERS, West Coast meeting. San Francisco, Calif. Aug. 18-20, 1948.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, Pacific general meeting. Spokane, Wash. Aug. 24-27, 1948.



"600" has been successfully used for many years as the solution to many extremely difficult bearing problems. It is a true bearing metal and—an entirely different one. "600" can be drawn or forged and readily fabricated in a great variety of sizes and shapes.

Many thousands of auto and truck transmissions have their reverse idler gears running on shafts of "600". A large quantity of it has been very successfully used for pump rods and other purposes where lubrication may be neglected. "600" IS IDEAL FOR PROPELLER SHAFTS IN POWER BOATS AND HUNDREDS OF OTHER USES, SUCH AS SPINDLES, SEAL RINGS, BEARING RINGS, WORM GEARS, CONNECTING RODS, CAMS, THRUST WASHERS, SUPERCHARGER SHAFTS, ELECTRICAL, AIRCRAFT AND AUTOMOTIVE EQUIPMENT, CONTROL APPARATUS AND MARINE HARDWARE.

"600" SERIES

BEARING METAL
FOR TOUGH JOBS

- **High strength**
- **Resistance to wear**
- **Corrosion resistant**

LIGHTER WEIGHT

Higher speeds and lighter weights are being demanded by leading designers of the most modern equipment. "600" Metal is specified for bearings because of its adaptability to meet the most exacting requirements. "600" Metal is approximately 8% lighter in weight than phosphor bronze alloys.

If you have a bearing problem, write us. We will supply you with samples of material for testing your own application. A complete booklet on "600" Series Alloys is yours for the asking.

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BOOK REVIEWS

Modern Plywood

Modern Plywood—Second Edition. *By Thomas D. Perry. Published by Pitman Publishing Corp., New York, 1948. Cloth, 6¼ x 9¼ in., 458 pages. Price $6.00.* The text has been extensively revised and includes the latest improvements in plywood manufacturing and utilization. Uses for plywood are classified with respect to aircraft construction, furniture and allied industries, boats and ships, containers and shooks, construction and building, etc.

Among the new or expanded subjects are barking logs, reeling green veneer, plymetal, sandwich constructions, aircraft and marine plywood, molded vs. formed plywood, progressive gluing, scarf jointing, radio frequency heating, and resistance heating. Material on the history, advantages and characteristics of plywood, plywood and veneer manufacturing, plywood in industry, adhesives for plywood, high density plywood, testing for adhesive strength, and new photos and tables have been added.

A glossary of the terms used in the plywood industry is included.

Industrial Electric Furnaces and Appliances

Industrial Electric Furnaces and Appliances, Volume II. *By V. Paschkis. Published by Interscience Publishers, Inc., New York, 1948. Cloth, 6¼ x 9¼ in., 320 pages. Price $8.00.* This volume is divided into three chapters: Resistance Furnaces and Appliances; Induction and High-Frequency Capacitance Heating; and Selection of Furnaces.

The first portion of the first chapter, under the heading "Indirect-Heat Furnaces," covers the following subjects: Furnace Size and Heating Time; Useful Heat; Furnace Parts; and Furnace Design. "Direct-Heat Furnaces" are covered in the second portion; and the third portion, under the heading "Appliances—Resistance Type," discusses Purpose and Classification; Direct-Heat Appliances; and Indirect-Heat Appliances (Resistance Type).

The second chapter "Induction and High-Frequency Capacitance Heating" consists of an Introduction and sections on High-Frequency Power Supply, Induction Furnaces

15 K. W. TOCCO unit brazing tools.

with TOCCO* Induction Heating

A large midwestern manufacturer of automotive parts reports the following savings from salvaging high-speed lathe tools with TOCCO induction heating:

> "The large tool shown here costs $17.00. It is eight inches long but formerly was discarded after four inches had been used. Now we use it all; the four inch stub is TOCCO-brazed to a four inch shank and we have a new tool for the cost of grinding and brazing—46¢, of which only 6¢ is the cost of TOCCO-brazing.
>
> "This process, applied to the many high-speed tools we use, provides a monthly savings of $2,000. The TOCCO Machine paid for itself completely in less than two months."

TOCCO Engineers stand ready to analyze *your* soldering, brazing or heat-treating problems to produce similar cost-cutting results.

THE OHIO CRANKSHAFT COMPANY

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FREE BULLETIN

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and Appliances, and High-Frequency Capacitance (HFC) or Dielectric Heating.

The last chapter is devoted to Selection of Furnaces.

Metallurgy for Engineers

MODERN METALLURGY FOR ENGINEERS—SECOND EDITION. *By Frank T. Sisco. Published by Pitman Publishing Corp., New York, 1948. Cloth, 6¼ x 9¼ in., 499 pages. Price $5.00.* A revised and enlarged edition of this excellent book is necessary because of the notable strides made by metallurgy since the publication of the first edition in 1941.

Two new chapters on hardenability of steel and one or more sections in practically every other chapter have been added. A considerable portion of the material contained in the first edition has been at least partially re-written.

The subjects covered include: metallurgy and engineering; the fundamental structure of metals and alloys; the manufacture of iron and steel; the composition of carbon and alloy steels; the constitution of steel; fundamentals of the heat treatment of steel; the operations of heat treatment; the significance of the static properties of metallic materials; the significance of the dynamic properties of metallic materials; machinability, wear resistance and deep-drawing properties; carbon steel as an engineering material; gray cast iron and malleable cast iron; low-alloy steels as engineering materials; fundamentals of hardenability; the hardenability of carbon and low-alloy steels; high-alloy steels as engineering materials; tool steels, die steels and cemented hard carbides; precipitation hardening and the constitution of nonferrous alloys; light alloys as engineering materials; copper and copper-base alloys as engineering materials; miscellaneous heavy nonferrous alloys; corrosion and corrosion resistance; and the effect of temperature on the mechanical properties of ferrous and nonferrous alloys.

Other New Books

PROCEEDINGS OF THE 34TH ANNUAL CONVENTION, AMERICAN ELECTROPLATERS' SOCIETY. Published by *American Electroplaters' Society, Box 168, Jenkintown, Pa., 1948. Cloth, 6 x 9 in., 308 pages. Price $10.00.* Contains papers on electroplating and discussions presented at the technical sessions at Detroit.

AN INTRODUCTION TO THE PHYSICS OF METALS AND ALLOYS. *By W. Boas. Published by John Wiley & Sons, Inc., New York, 1947. Cloth, 6¼ x 9¾ in., 193 pages. Price $3.50.* The main principle developed in this book on the physics of metals is that the properties and the arrangement of the crystals determine the properties of polycrystalline aggregates. Based on lectures given at the University of Melbourne since 1939.

Materials & Methods

THE MAGAZINE OF MATERIALS ENGINEERING

The Principles and Uses of Simulated Service Testing

Through-Carburizing of Low Carbon Steel

New Synthetic Rubber Has High Oil and Heat Resistance

Characteristics of Aluminum Suit It for Outdoor Reflectors

Metal-Coated Plastics Combine Advantages of Both Materials

Economical Joining of Magnesium Through New Brazing Method

Indium Plated Lead Bearings Withstand High Stresses

Pickling Monel Metal

Grinding, Polishing and Buffing of Monel

Electroplated Coatings

Materials & Methods Manual No. 38

June 1948

PUBLISHED SINCE 1929 AS METALS AND ALLOYS